Appendix Table of Contents

Appendix CD

System Analysis and Project Resources Inventory

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Questions for irrigation system analysis for each field being considered for an IFDM system

1. What type of irrigation is currently being used?
2. Will it continue to be used? If not what will be used?
3. For surface system
   - ❑ furrow run length
   - ❑ source of water – well, water district, open channel, piped
   - ❑ head ditch – lined or unlined
   - ❑ gated pipe, siphons
   - ❑ tailwater recovery system – pits, number of fields collected
   - ❑ surface grade of field (%) – how maintained?
   - ❑ mobile lab analysis
4. For sprinklers systems
   - ❑ size of laterals and mains
   - ❑ solid-set or movable – hand or automated
   - ❑ sprinklers sizes
   - ❑ lateral and sprinkler spacing
   - ❑ operating pressure
   - ❑ age of system
   - ❑ source of water – well or district
5. For drip systems
   - ❑ surface or subsurface – depth of installation for SDI
   - ❑ lateral spacing
   - ❑ type of drip tubing – discharge rate
   - ❑ water source
   - ❑ operating pressure
6. Cropping pattern – continue or change?
7. Depth of application applied for each crop?
8. Surface runoff (y or n) how much?
9. Preplant irrigation (y or n) how much?
10. Irrigation Scheduling (y or n) what method?
11. Multiple irrigation system for crop? i.e. sprinkler then furrow
12. Salinity problem areas?
13. Water-logging problems?
14. Shallow groundwater (y or n) depth to groundwater?
15. Drainage system in field? (y or n) controlled?

Summary table of the existing system and projected improvements by field

Parameters	Before	After
System type		
System configuration		
Total Application		
Surface runoff		
Irrigation Efficiency		
Maximum allowable depletion		
Leaching fraction		
Crops		
Surface grade		
Operation and maintenance costs		

Questions for surface and subsurface drainage system analysis for each field being considered for an IFDM system

1. Surface drains (y or n)?
   - ❑ depth and spacing – cross-sectional shape
   - ❑ collect subsurface drainage water (y or n)?
   - ❑ collect water from subsurface drainage sumps
   - ❑ discharge point
   - ❑ Tailwater pit (y or n) size,
2. Subsurface drains
   - ❑ Lateral depth and spacing
   - ❑ Lateral diameter
   - ❑ Lateral configuration (gridiron, herringbone, random)
3. Main line depth, size and location.
   - ❑ How many fields served
4. Control structures (y or n)?
   - ❑ how many and where located?
   - ❑ what type of control structures?
5. Sumps and pumped drains (y or n)?
6. Discharge to open drains (y or n)?
7. Drain lateral configuration relative to surface grade. (parallel or perpendicular)
8. Water table response to irrigation and with time during growing season
9. Drainage sump outlet – metered flow

Summary table of drainage system design and operation

Parameters	Existing	Proposed
Area drained (ac)		
Annual discharge (ac- ft)		
Drainage intensity (ft drain pipe/acre)		
Drainage water quality (dS/m)		
Drain lateral spacing (ft)		
Drain lateral depth (ft)		
Drain lateral diameter (in)		

IFDM Project Resources Inventory

The following is a listing of items to be inventoried and available as required for system design calculations and development of drawings:

a) Farming unit legal boundaries map (including easements and right-of-ways)

b) Existing field boundaries map

c) Existing irrigation and general farm unit infrastructures (including tail water reuse and drainage facilities)

- ❑ Contour maps
- ❑ Soils maps
- ❑ Current cropping patterns & history
- ❑ Sites to be preserved (e.g. wetlands and historical sites)
- ❑ Location of representative CIMIS sites
- ❑ Location of nearest IFDM system
- ❑ Location of neighboring installation that could be potentially sensitive to IFDM activities
- ❑ Location of nearest groundwater monitoring sites (with available records and studies on groundwater movement and quality)
- ❑ Location of irrigation water supply infrastructure (surface and ground) and water quality records
- ❑ Location of major surface water storm drainage ways and structures that could impact the farming unit

d) Electrical power supply facilities available to the farming unit

e) Farming unit imported irrigation water entitlements of contracts

f) Inventory of existing farming unit irrigation equipment (spiles, sprinklers, pipe, valves, gated pipe, micro-sprinklers, portable drip, pumping units, etc.)

g) History and current status of land forming practices on specific fields.

h) Current farming practices relative to improving root zone permeability and effective water storage.

i) Identify ground water movements both onto and off the farming unit that could impact the volume or quantity of groundwater to be handled by the IFDM system.

A salt balance calculation should be attempted for the farming unit. This balance quantifies, on an annual basis, the volume of salts imported with the irrigation water. An effort also is made to quantify the salts, if any, currently being exported from the farming unit. The difference in the amounts is the salts being sequestered on the farming unit. This volume must be managed by the IFDM system. First improved water management can reduce the total volume of salts imported. Second a process of concentrating the irrigation water ultimately results in the production of solid crystals in the solar evaporator.

Farming Unit Design

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The following is an example of an approach to determining irrigation and drainage flows for a hypothetical IFDM system sited on 640 acres. It highlights the impact on water management associated with irrigation system selection, water quality, and cropping patterns. The calculation involves estimating the water requirements, the deep percolation losses, and the resulting size of the production areas for salt tolerant plants and halophytes. Integration is involved in that after irrigation of salt sensitive crops there will be successive reuse of drainage water on the salt tolerant crops and halophytes for disposal. The total number of reuses prior to disposal in the solar evaporator or salt sequestering facility will depend on the irrigation management and the size of each production area.

It must be emphasized that while the following calculation protocol is meant to be general, scientifically rigorous, and accurate, it is based on **arbitrary** choices of specific crops and irrigation systems and water management schemes. Consequently, the numerical results of using other cropping and irrigation systems assumptions will give different numerical results. Other basic assumptions are:

1. All of the estimated deep percolation losses are collected by the drainage system. This is a very conservative estimate and serves to give an upper bound on the estimate of flow to the solar evaporator. Deep percolation losses were assumed to occur uniformly throughout the irrigation season. This might be a good approximation of deep percolation under a drip system but not a furrow system.
2. Time delays between the application of irrigation water and the appearance of that water in the tile drainage outlets is a period short enough to not affect the fundamental integrity of the design protocol.
3. Irrigation water applications, both timing and amount, are designed and scheduled using modern moisture balance calculations.
4. Canal supply water has a conductivity of 0.40 dS/m.
5. Other related assumptions and calculations are based on the climate, topography, and soils of the west side of the San Joaquin Valley.

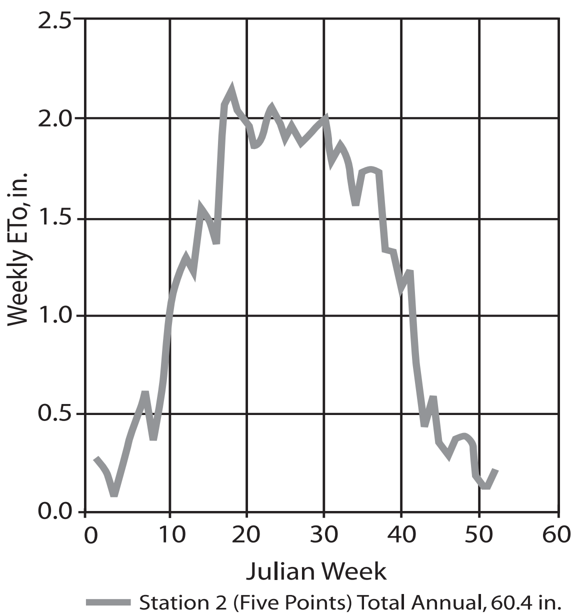

Fig. 1. Weekly Eto at West Side Research and Extension Center CIMIS Station.

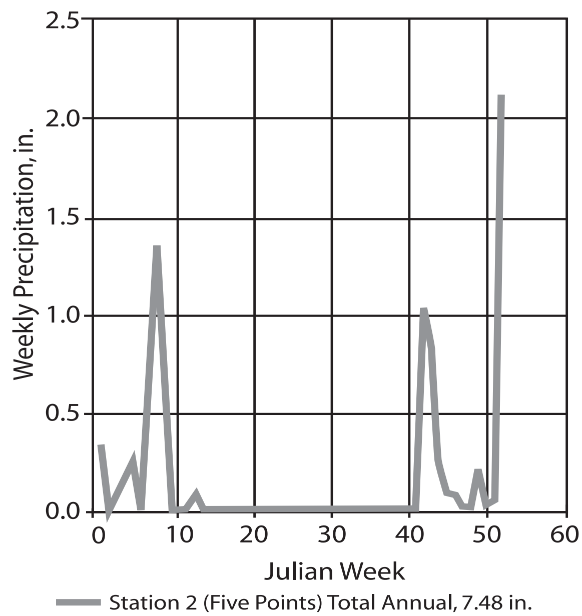

Fig. 2. Weekly precipitation at West Side Research and Extension Center CIMIS Station.

The calculations begin with an overall understanding of the climatic condition existing of the site. Figure 1 shows the weekly ETo readings for 2004. The potential evapotranspiration was 60.46 in. The rainfall in 2004 was 7.48 inches. The ETo readings will be used to calculate crop water requirements. CIMIS Station 2 at Five Points is used in the calculation and is representative of the west side of the San Joaquin Valley. Rainfall amounts are also useful in water balance and other calculations (e.g. predicting storm runoff.) Figure 2 shows the weekly precipitation readings for 2004.

Combining data from Figures 1 and 2 allows for the following observations:

The annual deficit between precipitation and ETo was 52.92 in. which means that irrigation is necessary for crop production and there is the potential for disposal of drainage water through crop water use.

From Julian weeks 10 thru 41, there was no rainfall. This simplifies the water balance calculation and minimizes the risk of storm water runoff from the solar evaporator/salt concentrator (SE/SC) installation. This period represents the growing period when the most agronomically productive crops will be irrigated.

Shown in Table No. 1 are the assumptions used in the calculation protocol described in the following section:

Table No. 1 Summary of assumptions associated with cropped areas used in sample calculations

Crop	Irrigation Method	Plant Date	Harvest Date	Comments
Alfalfa	Sprinkler	Cont.	Cont.	
Cotton	Furrow	03/28/04	10/15/04	Gated pipe
Tomatoes	Drip (tape)	03/03/04	8/11/04	
Jose Tall Wheat grass	Basin	Cont.	Cont.	Ditch
Halophytes/ Salt-Tolerant Forages (etc.)	Basin	Cont.	Cont.	

Planting and harvesting dates were assumed but are easily changed in the calculations protocol. Scientific symbols, data sources, and documents are identified in Table No. 2:

Table No. 2 Data Sources and Documents Identified

Symbol	Units	Definition	Source
ETo	in./day	Reference evapotranspiration	CIMIS web site
Kc	Ratio	Crop coefficient	1) "Crop water use in California" Bulletin 113-4, CADWR, April, 1986 2) "Crop water requirements" Irrigation and Drain. Paper #24, FAO, 1977
ETc	in./week	Net crop water requirements	ETc= ETo (Kc)
ECw	dS/m	Irrigation Water salinity	"Water quality for agriculture" Paper #29, FAO, 1985
ECe	dS/m	Soil water salinity	

Refinements in crop coefficients from other sources are easily factored into the calculations protocol. This is especially true of the salt tolerant crops as scientists attempt to identify crops with more commercial value (e.g. salt tolerant grasses being developed for turf and landscape uses.)

Table No. 1 identifies the crops used in the sample calculations. Alfalfa, cotton and tomato will be the crops in the initial production areas that are irrigated with good quality water. Jose Tall Wheat Grass and Halophytes/Salt-Tolerant Forages etc. will be the crops in the reuse areas that are irrigated with drainage water.

Alfalfa Field (160 acres) Initial use Design Calculations Summary

Crop: Alfalfa

Irrigation System: Sprinkler, portable solid set

Sprinkler Losses: -spray, 3%
-pattern, 10%
-operational, 5%

Deep percolation efficiency, 100%
Operational efficiency, 86% (6 days/week operation)
Irrigation water salinity, 0.4 dS/m

$LR = EC_w / (5*(EC_e) - EC_w)$

Calc: Leaching Requirement (LR)
Use EC_E= 2.0 dS/m to provide 100% of yield-potential

$$LR = \frac{0.40}{5(2.0) - 0.40}$$

LR = 0.042 or 4.2 %

This is the LR formula found in FAO 29 and is not as conservative an estimate as found in Handbook 60 and thus results in a reduced estimate of the leaching requirement.

Calc: Application Efficiency (AE), %

AE = (1-.03) (1-.10) (1-.05)
= (.97) (.90) (.95)
AE = 0.829 or 82.9 %

At this point the designer should compare the leaching requirement LR to the actual leaching fraction (LF) calculated as 100% - AE. This is an indication whether the LF resulting from the operation of this type of irrigation system will be adequate to meet the LR. In this case the LF will be approximately 17% which is greater than the LR indicated in the above calculation. Therefore there is no need to include additional water into the following calculations.

Calc: Irr. Supply Flow Rate, gpm

$$Q_S = \frac{ETc}{(0.829)} \frac{(18.9)(160)}{7}$$

Q_S = ETc (521.1) gpm

Note: Q_P, pumping flow rate, gpm

$$Q_P = \frac{Q_S}{.86} = ETc\ (605.9),\ \text{gpm}$$

This is the weekly average discharge to the field based on crop water requirement which is the basis for the computed average weekly deep percolation.

Calc: Deep percolation flow Rate, gpm

$$Q_d = ETc \ \frac{1}{(.90)(.95)} - 1 \quad \frac{(18.9)(160)}{7}$$

$$Q_d = ETc \cdot (73.3), gpm$$

The average equivalent drain flow if all the deep percolation is collected is given by the above equation. This represents the upper limit on flow from the drainage system. Perennial crop such as alfalfa and grasses will require water throughout the year. However, the winter requirement is very low and will probably be met with rainfall. The irrigation season will not start until March or April.

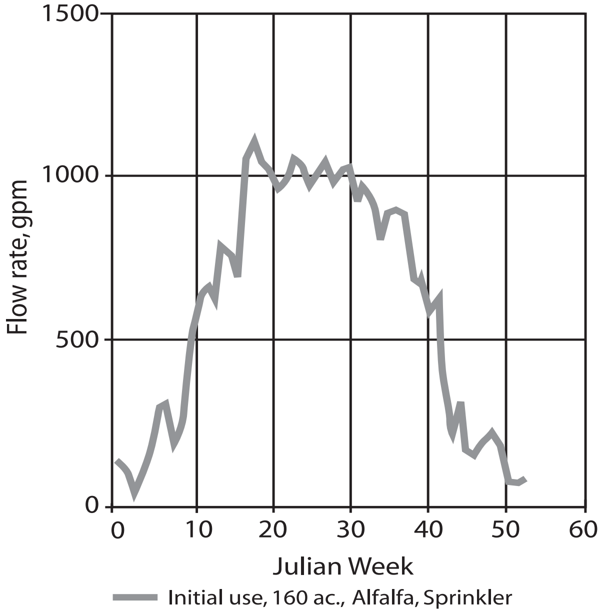

Fig. 3. Irrigation supply flow rate for alfalfa field

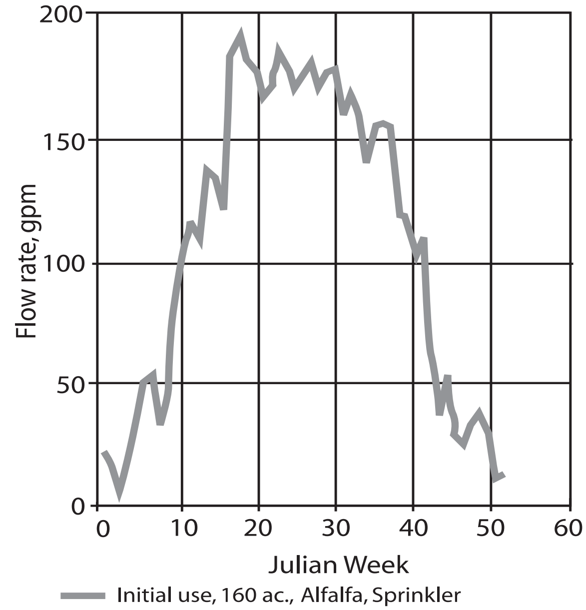

Fig. 4. Drainage flow rate for alfalfa field

Note that the weekly ETc values were determined by using a Kc value of 0.95 and the ETo values from Figure 1. The use of a Kc of 0.95 would not account for any harvests occurring. The supply flow and the drainage flows are given in Figures 3 and 4 for comparison.

The midsummer supply flow rate to the alfalfa field is about 1000 gpm (2.23 cfs.) The sprinkler system pumping flow rate operating 6 out of 7 days per week is about 1200 gpm (2.67 cfs.) What will be required for the drainage design is to determine an irrigation schedule that gives the dates of irrigation and depth of irrigation with the assumed deep percolation losses. This will be used by the drainage designer to complete the design of the drainage system.

Cotton Field (160 acres) Initial use Design Calculations Summary

Crop: Cotton
Irrigation System: Furrow/ gated pipe
System Losses: -tail water, 5%
-pattern, 20%
Deep percolation efficiency, 100%
Operational Efficiency, 86% (6 days/ week operation)
Irrigation water salinity, 0.4 dS/m

Calc: Leaching Requirement
Use EC_E= 7.7 dS/m to provide 100% of yield-potential

$$LR = \frac{0.40}{5(7.7)-0.40}$$

LR = 0.010 or 1.0 %

Note that as the permissible ECe increases for good quality water the LR is reduced.

Calc: Application Efficiency, %

$$\begin{aligned} AE &= (1-.05)\,(1-.20)\,(1-.01) \\ &= (.95)\,(.80) \\ AE &= 0.76 \text{ or } 76\ \% \end{aligned}$$

Note the projected losses exceed the LR and again no additional water is required in the flow computation.

Calc: Irr. Supply Flow Rate, gpm

$$Q_S = \frac{ETc}{(0.76)}\ \frac{(18.9)\,(160)}{7}$$

Q_S = ETc (568.4), gpm

Note: Q_P, pumping flow rate, gpm

$$Q_P = \frac{Q_S}{.86}$$

Calc: Drain System Flow Rate, gpm

$$Q_d = ETc\left(\frac{1}{(.80)} - 1\right)\frac{(18.9)\,(160)}{7}$$

$Q_d = ETc(108)$, *gpm*

Calc: Tail Water Flow Rate, gpm

$$\begin{aligned} Q_T &= \text{ETc } (568.4)\,(.05) \\ &= \text{ETc } (28.4), \text{ gpm} \end{aligned}$$

Tail water quality should be the same as the supply water quality, 0.4 dS/m.

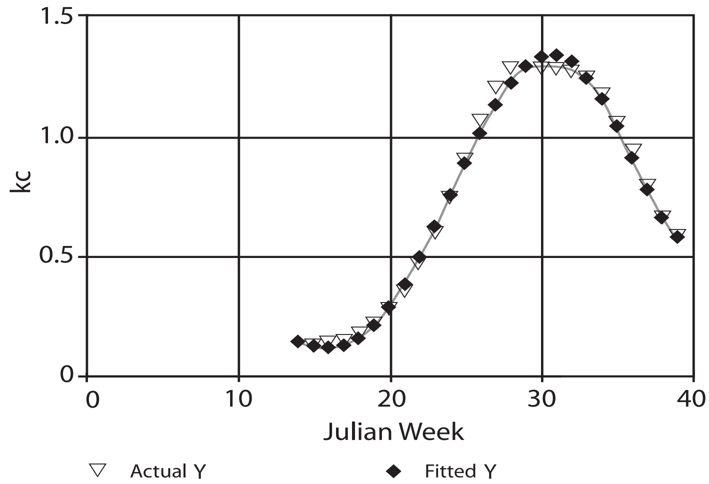

Fig. 5. Kc values vs. Julian weeks for cotton field

This calculation follows the same sequence as for the alfalfa field. The average weekly Kc values for cotton are shown in Figure 5. The ETo values from Figure 1 are multiplied by the Kc values in Figure 5 to give the ETc values.

These ETc values are used in the calculation protocol to give in turn the "Irrigation Supply Flow Rate," "Drainage System Flow Rate" (see Figure 6,) and the "Tail Water Flow Rate" (see Figure 7.)

The relationship between the "Supply Flow Rate" and the "Drainage System Flow Rate" suggests a reduction in water volume of again about 80-81%. With this surface system, a tail water discharge is expected. Since the tail water quality should match the water supply quality (0.4 dS/m) it could be safely introduced into the original supply for use on salt sensitive crops.

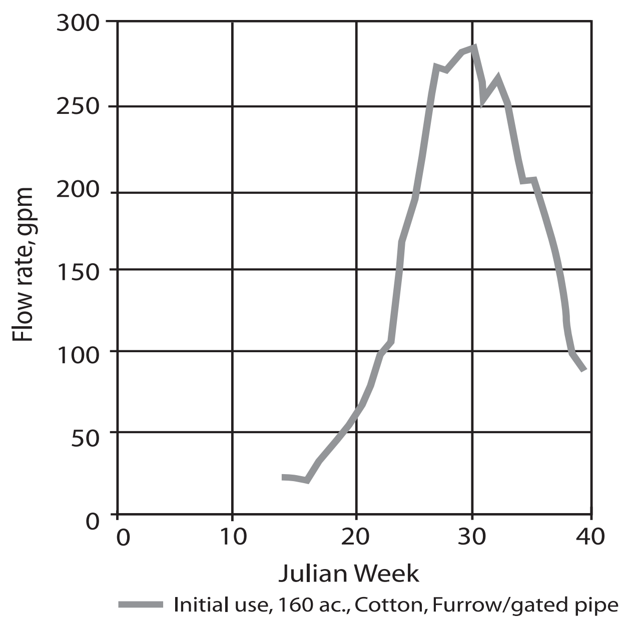

Fig. 6. Drainage system flow rate for cotton field

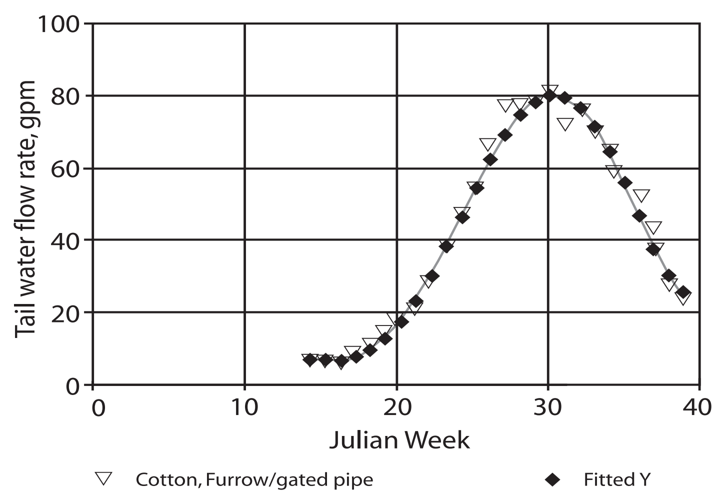

Fig. 7. Tail water flow rate vs. Julian weeks, cotton field

The design example gives the following details for the tomato field:

Tomato Field (160 acres) Initial use Design Calculations Summary

Crop: Tomatoes

Irrigation System: Non-pressure compensated buried drip tape

Sprinkler Losses: -pattern, 10%

Deep percolation efficiency, 100%

Operational efficiency, 100%

Irrigation water salinity, 0.4 dS/m

<u>Calc</u>: Leaching Requirement

$$LR = \frac{0.40}{5(2.5)-0.40}$$

$$LR = 0.033 \text{ or } 3.3\%$$

<u>Calc</u>: Application Efficiency, %

$$AE = (1-.10)$$
$$= (.90)$$

$$AE = 0.9 \text{ or } 90\%$$

There are adequate deep percolation losses with a drip system to meet the LR. However, fields irrigated with a drip system may require periodic leaching if there is inadequate rainfall.

<u>Calc</u>: Irr. Supply Flow Rate, gpm

$$Q_S = \frac{ETc}{(0.90)} \frac{(18.9)(160)}{7}$$

$$Q_S = \text{ETc } (480) \text{ gpm}$$

<u>Calc</u>: Drainage System Flow Rate, gpm

$$Q_d = ETc\left(\frac{1}{(.80)} - 1\right)\frac{(18.9)(160)}{7}$$

$$Q_d = ETc(48), gpm$$

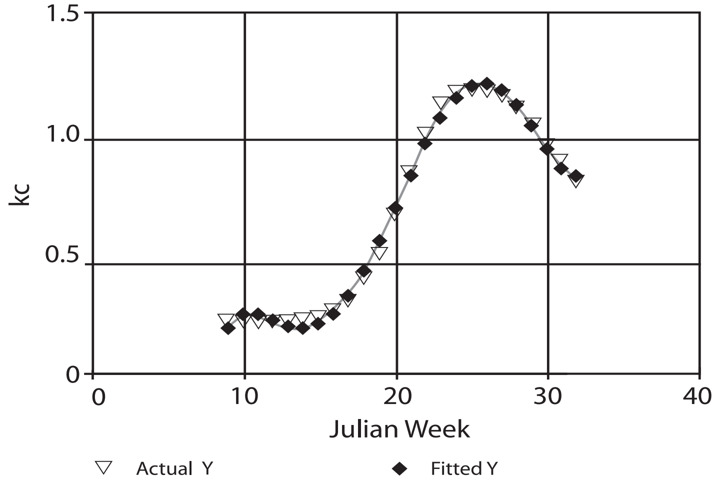

Fig. 8. Kc values vs. Julian weeks for tomato field

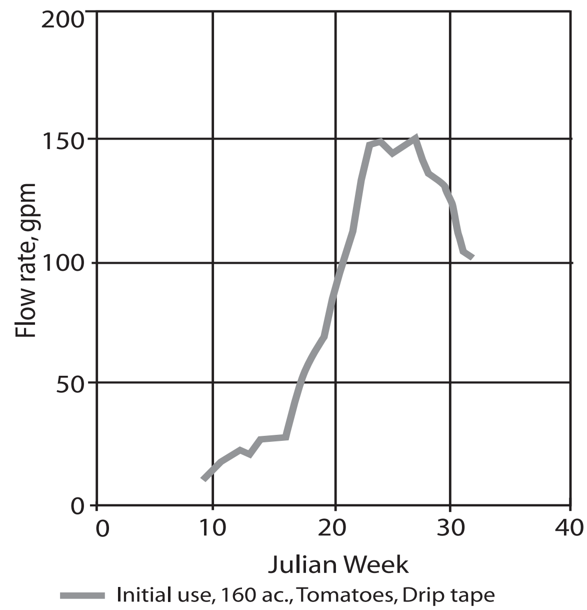

Fig. 9. Drainage system flow rate for tomato field

The calculation follows the same sequence as for the alfalfa and cotton fields. The Kc values are shown in Figure 8. The ETo values from Figure 1 are multiplied by the Kc values in Figure 8 to give the ETc values. These ETc values are used in the calculation protocol to give in turn the "Irrigation Supply Flow Rate," and the "Drainage System Flow Rate" (see Figure 9.)

The relationship between the "Irrigation Supply Flow Rate" and the "Drainage System Flow Rate" suggests a reduction in water volume of between 85-90%.

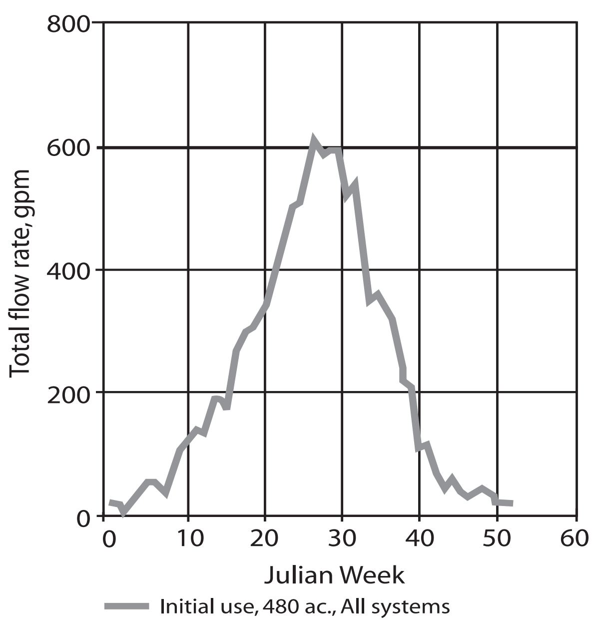

Fig. 10. Drainage system flow rate from alfalfa, cotton, and tomato fields (Initial Production Areas)

The calculations required for first reuse area relate directly to the drainage flow rates and water quality from the first production areas. Shown in Figure 10 is the total of the calculated drainage system flow from the alfalfa, cotton, and tomato fields. This is the type of analysis that will be needed to develop a water management program and cropping alternatives.

The shape of the curve reflects the long seasonal contribution by the alfalfa and the shorter seasonal contribution by the cotton and the tomatoes.

The design protocol gives the following details for the first reuse area.

First reuse area Calculations Summary

Crop: Jose Tall Wheat Grass
Irrigation System: Basin, ditch
Sprinkler Losses: -pattern, 20%
-tail water, 5%
Deep percolation efficiency, 100%
Operational efficiency, 86% (6 days/week operation)
Irrigation water salinity, blended from Initial use as follows:

Calc: Leaching Requirement

$$LR = \frac{0.70}{5(12)7.0} - 0.13 \qquad \text{OR}$$

LR= 0.130 or 13.0%

Calc: Application Efficiency %

$$AE = (1-.20)(1-.05)$$
$$= (.80)(.95)$$

$$AE = 0.76 \text{ or } 76\%$$

This is a point where it is important to compare the LR to the AE. In the first reuse the irrigation water quality was blended to about 7 dS/m and the increase was to 12 dS/m which is approximately the ground water quality at many locations on the west side SJV. A 13% leaching requirement was indicated and the inherent irrigation efficiency as 76% which means there was approximately 24% of the water moving through the soil so the LR was meet.

Calc: First reuse area requirements, ac.

$$Q_S = \frac{ETc}{(0.76)} \frac{(18.9)\,(A, acres)}{7} \qquad \text{OR}$$

$$A = \frac{Q_S}{ETc}\,(0.28),\ acres$$

Calc: Irr. Supply Flow Rate, gpm

$$Q_S = \frac{ETc}{(0.76)} \frac{(18.9)\,(A)}{7},\ \text{gpm}$$

$$Q_S = (ETc)(A)(3.55)\ \text{gpm}$$

Calc: Drain System Flow Rate, gpm

$$Q_d = ETc\left(\frac{1}{(.80)} - 1\right)\frac{(18.9)\,(A)}{7}$$

$$Q_d = ETc(.67),\ gpm$$

In this calculation the Q_S will be the drainage flow collected from the initial production areas as shown in Figure 10. The data in Figure 10 will vary with time as will ETc. The problem is that there is an inverse relationship between Q_S and ETc. Drainage flow data from the SJV show high drain flows in winter reflecting pre-plant irrigation and spring from the first irrigation. These data were collected during times when furrow irrigation was the prevalent irrigation method. Switching to sprinklers and reducing the applied water should result in reduced drainage flows. The ETc is also lowest in winter when supply will be greatest. Provision will have to be made to store drainage flows as shallow ground water for discharge later in the year when ETc rates have increased.

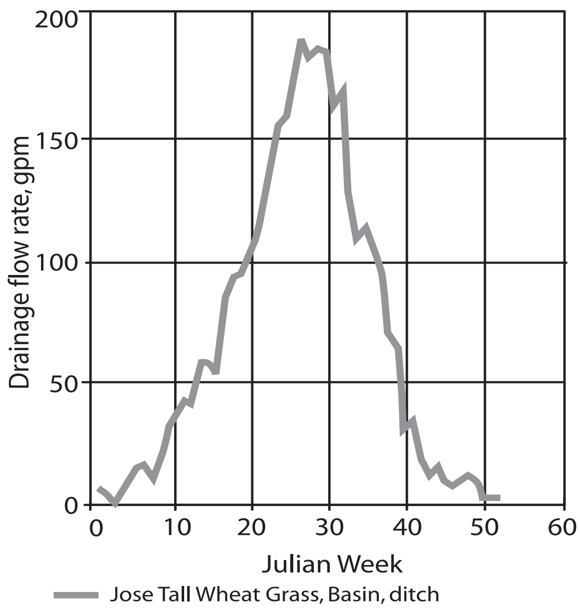

Fig. 11. Drainage system flow rate from first reuse area

Water applications on the reuse fields will have to be carefully managed to keep it from becoming a "salt dump." Calculated full applications will have to be made to provide the leaching fraction and move the salts through the root zone to the drainage system. A sizable fraction (50-70%) of the area may have to be left dormant during late fall and early spring. The "Drainage System Flow Rate" from the first reuse is shown in Figure 11.

Halopyte/Salt-Tolerant Forages (etc.) use Area Calculations Summary

Crop: Halophytes / Salt-Tolerant Forages (etc.)
Irrigation System: Basin, ditch
Irrigation System Losses: -pattern, 20%
-tail water, 5%
Deep percolation efficiency, 100%
Operational efficiency, 100%
Irrigation water salinity, 7.58 dS/m

Calc: LR, Ratio

$$LR = \frac{7.58}{5(13.0) - 7.58}$$

Note: Use ECe of 13 dS/m which allows for a yield potential of 75% for tall wheat grass.

$$LR = 0.132 \text{ or } 13.2\ \%$$

Calc: App. Eff., %

$$AE = (1-.20)(1-.05)$$
$$= (.80)(.95)$$

$$AE = 0.760 \text{ or } 76.0\ \%$$

Calc: Halophyte / Salt-Tolerant Forages (etc.) Area Requirement, ac.

$$Q_S = \frac{ETc}{(0.760)} \frac{(18.9)\ (A, acres)}{7} \qquad \text{OR}$$

$$A = \frac{Q_S}{ETc}\ (0.28),\ acres$$

Calc: Irr. Supply Flow Rate, gpm

$$Q_S = \frac{ETc}{(0.760)} \frac{(18.9)\ (A)}{7}\text{, gpm}$$

$$Q_S = \text{ETc (A)(3.55), gpm}$$

Calc: Drain System Flow Rate, gpm

$$Q_d = \text{ETc} \left(\frac{1}{(.80)} - 1 \right) \frac{(18.9)\ (A)}{7}\text{, gpm}$$

$$Q_d = \text{(ETc)(A)(0.675), gpm}$$

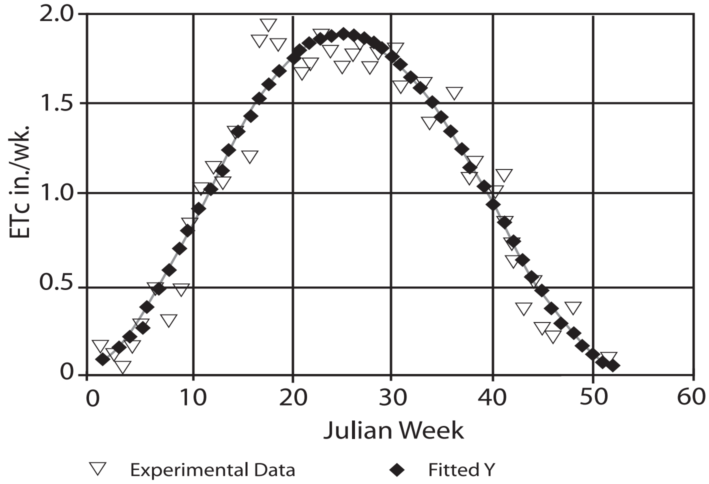

Fig. 12. ETc (in./wk.) vs. Julian weeks, Halophytes and Tall Wheat Grass

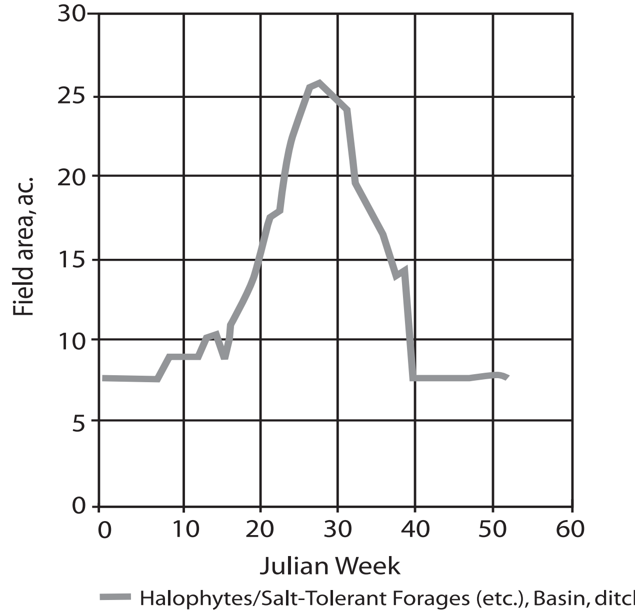

Fig. 13. Halophyte/Salt-Tolerant Forages (etc.) field area requirements

Shown in Figure 12 are the ETc values for crops having a crop coefficient (Kc) of 0.90. This is a reasonable estimate for halophytes/salt-tolerant forages, such as tall wheat grass. The ETc values are combined with the drainage system flow rates from Figure 11 in a formula (see Halophyte/Salt-Tolerant Forages [etc.] Area Calculations Summary) to allow for the calculation of the halophyte area requirements as shown in Figure 13.

The last calculation to be made in this section is the "Drainage System Flow Rate" for the halophytes/salt-tolerant forages (etc.). The results of that calculation are shown in Figure 14. The peak flow will occur during the summer months when there is the largest potential to dispose of water through evapotranspiration. The basic objective of an IFDM system is to dispose of saline drainage (in an environmentally sound manner) and to maintain a sustainable agronomic system. This will require careful water management to avoid sequestering salts in the root zone.

The examples of the design using different irrigation systems and water qualities demonstrates an approach to the decisions required as an IFDM system is developed. The deep percolation flow that was assumed to be the drainage flow is conservative on the high side and the actual timing of flows will be later than anticipated and lower than presented. The calculation shows other hydraulic data useful in the design and operation of the system (e.g. pumping flow rates.)

Each designer will have to develop their own procedures to estimate the flows. If the farm has existing drains with data describing the flow as a function of irrigation management and time through the seasons it will be a straightforward matter to sum the flows from each field as a function of time. Knowing the irrigation system management and crop it will be possible to make a good estimate of the effect of improving irrigation management and reducing deep percolation losses.

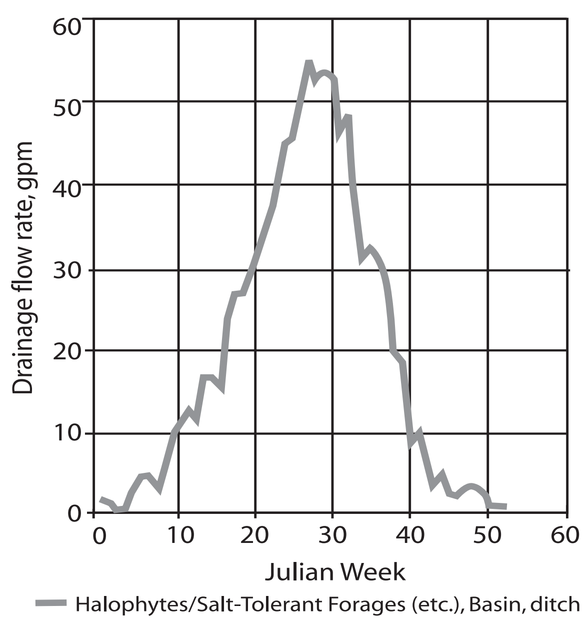

Fig. 14. Drainage system flow rate for halophytes/salt-tolerant forages.

Solar Evaporator for Integrated on-Farm Drainage Management System at Red Rock Ranch, San Joaquin Valley, California

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Abstract

A pilot solar evaporator demonstration project results to manage and concentrate subsurface drainage water effluent from a large scale farming operation is presented. The goal of this project is to collect information to develop a farm scale solar evaporator for the 640-acre Integrated On-Farm Drainage Management (IFDM) system at Red Rock Ranch and future IFDM systems in the San JoaquinValley of California. IFDM is a farming system that sequentially reuses subsurface drainage water to grow salt-tolerant crops. An enhanced evaporation system (solar evaporator) is the terminus of the system to achieve zero-liquid discharge. An IFDM system as defined in Article 9.7 Health and Safety Code, Section 25209.11, (c), (1-4), includes a solar evaporator. Highly concentrated agricultural subsurface drainage water collected from the IFDM system is discharged to the solar evaporator using timed spray sprinklers. Additional requirements for a solar evaporator are listed in Section 25209.11, (e), (1-4).

Objective

The purpose of this study was to gather, analyze, and evaluate data on evaporation rates of subsurface drainage water using various evaporative surfaces, nozzles, materials, and equipment so that a farm scale solar evaporator could be designed and constructed. The pilot solar evaporator was used to perform the following: 1) evaporate drainage water and recover salts, 2) to determine the optimum weather parameters for operating a solar evaporator, and 3) examine methods to control the potential for salt drift. The data obtained from the pilot solar evaporator will be used to design and construct a solar evaporator for the 640-acre farm at Red Rock Ranch.

Approach

In order to construct the pilot-scale solar evaporator at Red Rock Ranch, the following steps were performed: 1) test different types of nozzles (spray patterns, angles, and pressures) and surface materials, 2) evaluation of test data, 3) design, 4) construction, 5) operate and maintain the solar evaporator and collect data during seasonal conditions for evaporation rates, weather, wind and salt drift.

Data Collection

Figure 1 shows the module used to collect data on evaporation rates of subsurface drainage water using various evaporative surfaces, nozzles under various pressures, materials, and equipment. Nozzles were also tested by Center for Irrigation Technology for pressure, water discharge, mist dimensions (height, radius, mist density). The evaporative area was constructed at a 2% gradient for this study, calculated using Manning equation. The evaporative surface and reservoir were lined with plastic to prevent seepage. Three surface

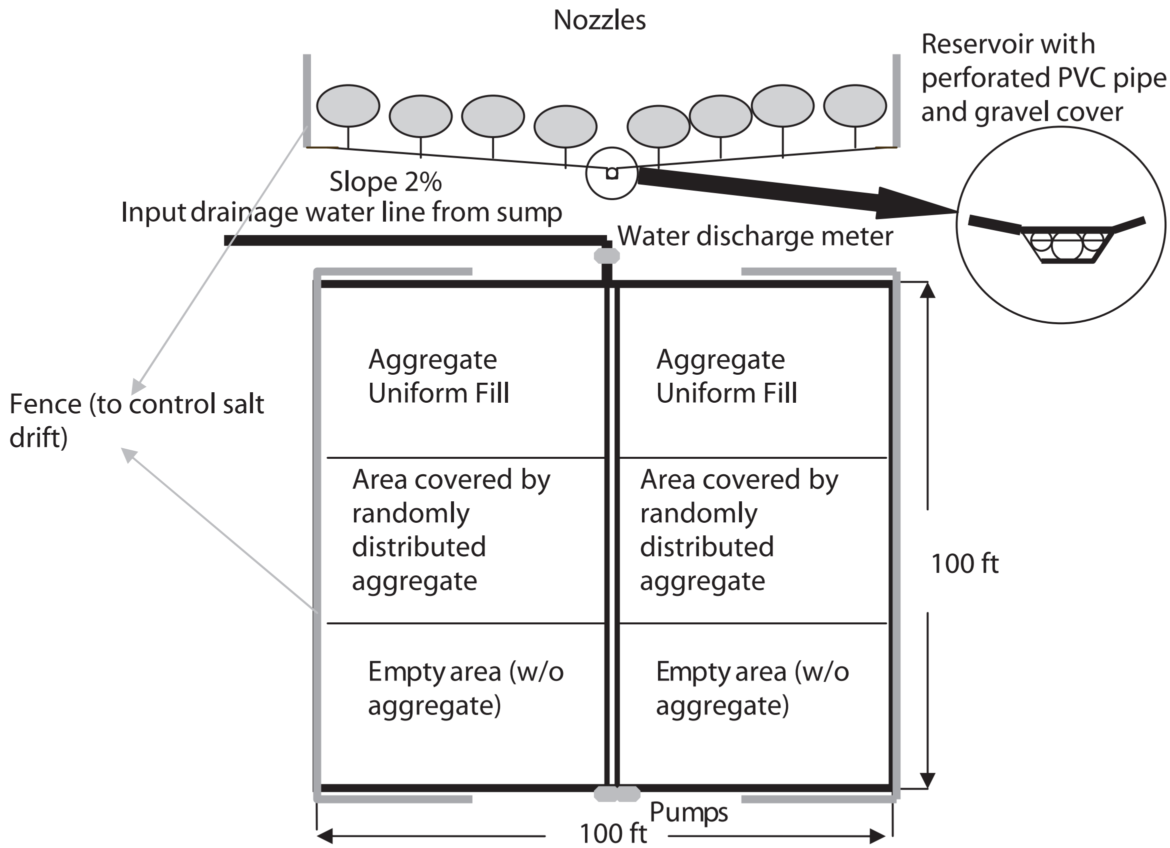

Figure 1: Project Module Profile and Plan.

materials were initially tested on the 100 ft x 100 ft evaporative area as follows: 1) 2-inch aggregate uniform fill; 2) 2-inch randomly distributed aggregate; and 3) surface w/o aggregate. Accessory equipment included two five-horse power pumps and various nozzles.

All quantitative and qualitative parameters (water discharges and pressures, rates of evaporation, chemical analysis for brines and salts) were measured using different types of meters, tools, and equipment.

Construction of Pilot Solar Evaporator

Once the optimum surface material was determined, the total evaporator surface area was reconstructed. The reservoir received drainage water to be evaporated and water recycled during the evaporation process. The reservoir consisted of perforated PVC pipes with a gravel cover. Testing of various nozzles was ongoing. A fence was installed in an attempt to control salt drift. A photo of the pilot solar evaporator and accessory equipment is shown in Figure 2. The pilot solar evaporator was operated over a one year period to collect data during seasonal conditions.

Figure 2: Pilot Solar Evaporator

Results

Two inch aggregate was selected as the optimum surface material for the evaporator surface constructed with a 2% gradient. Two industrial nozzles manufactured by BETE, BETE TF 12-170 and BETE TF 12-180 were the most effective in enhancing evaporation. These spray nozzles are made of brass, energy efficient, and clog-resistant. Spray characteristics are hollow cone spray pattern, spray angles 170 and 180 degrees, and flow rates 2.12-7.35 gpm for water pressures 5-60 psi. The data collected from the pilot project will be used to construct the farm solar evaporator.

During spring and fall seasons daily evaporation from SE-SC was 0.7-1.1 inch, but increased to 1.3-4.2 inches (Figures 3-A, 3-B) during summer months. Figure 3-B illustrates the evaporation from solar evaporator to the actual daily evaporation by CIMIS station, nozzle heights at 0.25 ft through 2.0 ft. The optimum time to operate the solar evaporator was found to be from May through September.

Salt was recovered from drainage water in four steps. The first step increased salt concentrations from 10-48 g/l; the second from 48-107 g/l; the third from 107-220 g/l; and the final step from 120-250 g/l or higher. The remaining brine, salt concentration 200-250 g/l, was evaporated using BETE TF 12-170 spray nozzles. Figure 4 shows the salts recovered from the operation of the pilot solar evaporator project.

The effect of wind on salt drift needs to be further studied. In June 2004, CIT researchers began a field study to monitor salt emissions of the solar evaporator. The field samples are being analyzed and the results of the analysis will be used with a dispersion model to calculate particle emission factors.

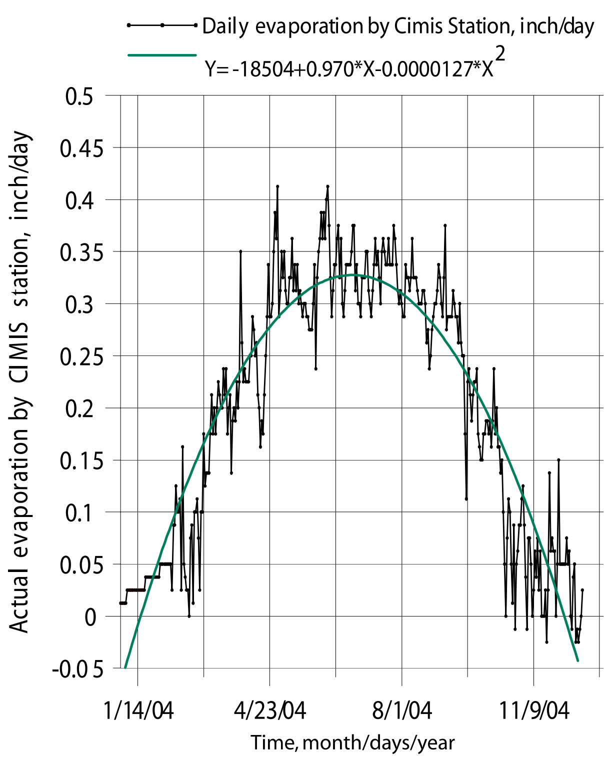

Figure 3-A

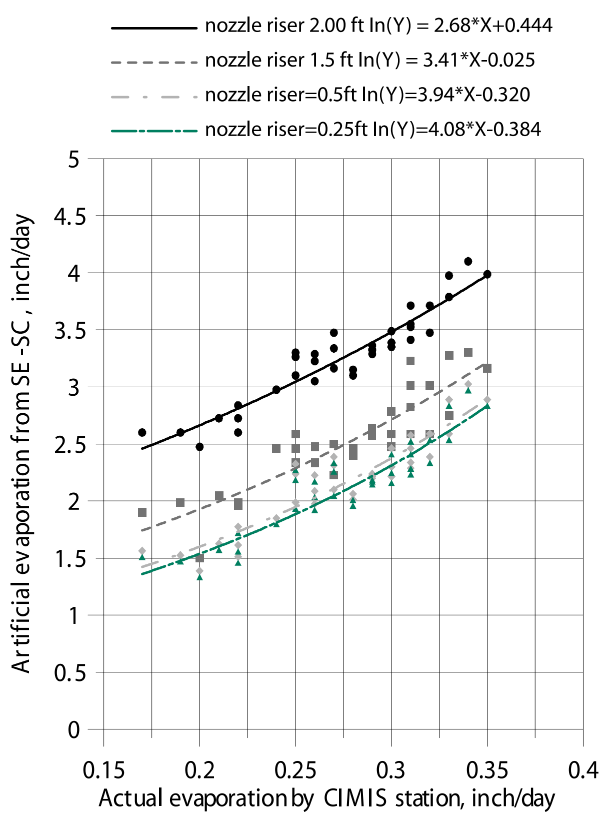

Figure 3-B

Figure 4: Salts Recovered from the Pilot Solar Evaporator

Conclusions

The data presented in this paper demonstrate that a simple and efficient, easy to operate; solar evaporator can be developed as a viable tool to manage agricultural subsurface drainage water within the boundaries of the 640-acre IFDM system at Red Rock Ranch. The data collected from this pilot study will provide a solid reference to designers to develop similar enhanced evaporation systems for IFDM projects and for management of brine effluents.

Reference

Chapter 6.5 of Division 20 of the Health and Safety Code, relating to water, Article 9.7, Section 25209.11

See Appendix CD for California Department of Water Resources PowerPoint Presentation of the Design of the Solar Evaporator for Integrated On-Farm Drainage Management System at Red Rock Ranch.

Drainage Water and Its Effect on Wildlife Resources

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I. Introduction

A goal of IFDM is to dispose of highly saline agricultural subsurface drainage water in an environmentally sound way that does not impact wildlife. Draft Title 27 Solar Evaporator Regulation states, *"The solar evaporator shall be operated to ensure that avian wildlife is adequately protected."*

Depending on the design and management of the solar evaporator, wildlife, such as shorebirds and waterfowl, may be attracted to the solar evaporator if standing water or scattered puddles are allowed to form. The saline subsurface drainage water may contain elevated selenium, which is the primary constituent of concern, and the hyper-saline water itself may impact wildlife.

II. Laws that Address Wildlife Issues

• California Code of Regulations (CCR) Draft Title 27 Solar Evaporator Regulations established minimum requirements for the design, construction, operation and closure of solar evaporators as components of IFDM systems with the intent of protecting wildlife from exposure to salt and selenium.

• California Environmental Quality Act (CEQA): environmental impact analysis is a component of CEQA, and delineates mitigation and monitoring requirements that may have to be incorporated into an IFDM system in order to ensure adequate CEQA compliance.

• Migratory Bird Treaty Act (MBTA) is enforced by both the USFWS and the CDFG.

• Federal Endangered Species Act (FESA) and the California Endangered Species Act (CESA) were created to protect species from extinction and are enforced by the USFWS and the CDFG, respectively.

The Central Valley Regional Water Quality Control Board currently is developing regulations regarding monitoring. The following is from Draft Title 27 Solar Evaporator Regulations, §22940:

Inspection – The CVRWQCB issuing a Notice of Authority to Operate a solar evaporator shall conduct authorized inspections in accord with §25209.15 of Article 9.7 of the Health and Safety Code to ensure continued compliance with the requirements of this article. The CVRWQCB shall request an avian wildlife biologist to assist it in its inspection of each authorized solar evaporator at least once every May. If an avian wildlife biologist is not available, the CVRWQCB shall nevertheless conduct the inspection. During the inspection, observations shall be made for compliance with §22910 (a) and (v), and the following conditions that indicate an unreasonable threat to avian wildlife:

(1) Presence of vegetation within the boundaries of the solar evaporator;

(2) Standing water or other mediums within the solar evaporator that support the growth and dispersal of aquatic or semi-aquatic macro invertebrates or aquatic plants;

(3) Abundant sustained avian presence within the solar evaporator that could result in nesting activity;

(4) An apparent avian die-off or disabling event within the solar evaporator;

(5) Presence of active avian nests with eggs within the boundaries of the solar evaporator.

A qualified wildlife biologist or agent identified by the Central Valley Regional Water Quality Control Board, may conduct the following biological surveys:

- Monitor for aquatic invertebrate activity if standing water is present for greater than 48 hours;
- Monitor bird activity (bird census, year round, monthly to twice per month);
- If nesting is detected, monitor nesting activity and nest fate (every 1-2 weeks from mid- March through July);

- If nesting is detected, collect egg selenium concentration data;
- Collecting and research take permits from the CDFG and USFWS are required for the collection of mammals, birds and their nests and eggs, reptiles, amphibians, fish and invertebrates.
- According to Draft Title 27 Solar Evaporator Regulations, §22940:

If active avian nests with eggs are found within the boundaries of the solar evaporator, the RWQCB shall report the occurrence to the USFWS and DFG within 24 hours, and seek guidance with respect to applicable wildlife laws and implementing regulations. Upon observation of active avian nests with eggs within the boundaries of the solar evaporator, all discharge of agricultural drainage water to the solar evaporator shall cease until (a) the nests are no longer active, or (b) written notification is received by the owner or operator, from the RWQCB, waiving the prohibition of discharge in compliance with all applicable state and federal wildlife laws and implementing regulations (i.e., as per applicable exemptions and allowable take provisions of such laws and implementing regulations).

III. Constituents of Concern

A. Selenium

Selenium originates from the natural weathering of cretaceous shale (rocks that have the highest selenium concentration 500-28,000 ppb); however, there are two human-related activities that have resulted in the mobilization and introduction of selenium into aquatic systems. The first activity is the irrigation of selenium-containing soils for crop production in arid to semiarid areas of the country. The other source is from the procurement, processing (i.e. oil refineries), and combustion of fossil fuels (Lemly and Smith, 1987).

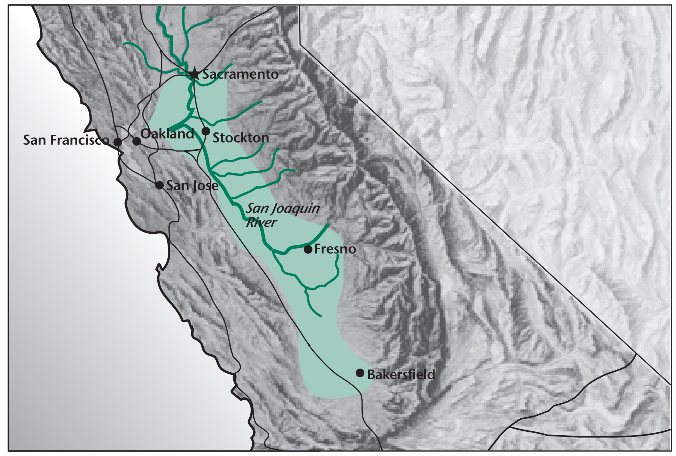

Figure 1. Land area with aquatic systems that maintain various levels of constituents of concern for wildlfe.

Selenium is a double-edge sword. Animals needs trace levels of the mineral in their diet for survival, but at levels slightly above trace amounts it can be very toxic. In addition, clinical signs for selenium deficiency are similar to selenium toxicity. Many veterinarians have misdiagnosed selenium toxicity as a selenium deficiency, resulting in adding selenium supplements to a patient's diet, which increased the toxicity response to a higher level.

The signs of acute selenium poisoning in laboratory animals include garlic breath, vomiting, dyspnea (difficulty or shortness of breath), tetanic spasms of the muscles, and respiratory failure (Koller and Exon, 1986). Acute poisoning of livestock is associated with plant material containing 400-800 ppm selenium (Eisler, 1985). "Alkali disease" is a livestock disease resulting from chronic selenium exposure; it is characterized by a lack of vitality, anemia, stiffness of joints, deformed and sloughed hooves, roughened hair coat, and lameness (Koller and Exon, 1986).

The most common signs of selenium poisoning in wild birds are emaciated adults, poor reproduction rates, embryonic deaths and deformities (missing or abnormal body parts, such as wings, legs, eyes, and beaks, and fluid accumulation in the skull), and adult mortality (Friend and Franson, 1999). In order to diagnose selenium poisoning, factors such as a history of potential exposure, gross developmental defects, microscopic lesions (evidence of chronic liver damage), and selenium concentrations in tissues, food, water and sediment must be examined.

Plants and invertebrates in contaminated aquatic systems can accumulate selenium, which can sometimes reach levels that are toxic to birds and other organisms that eat them (Friend and Franson, 1999) as shown in Figure 1.

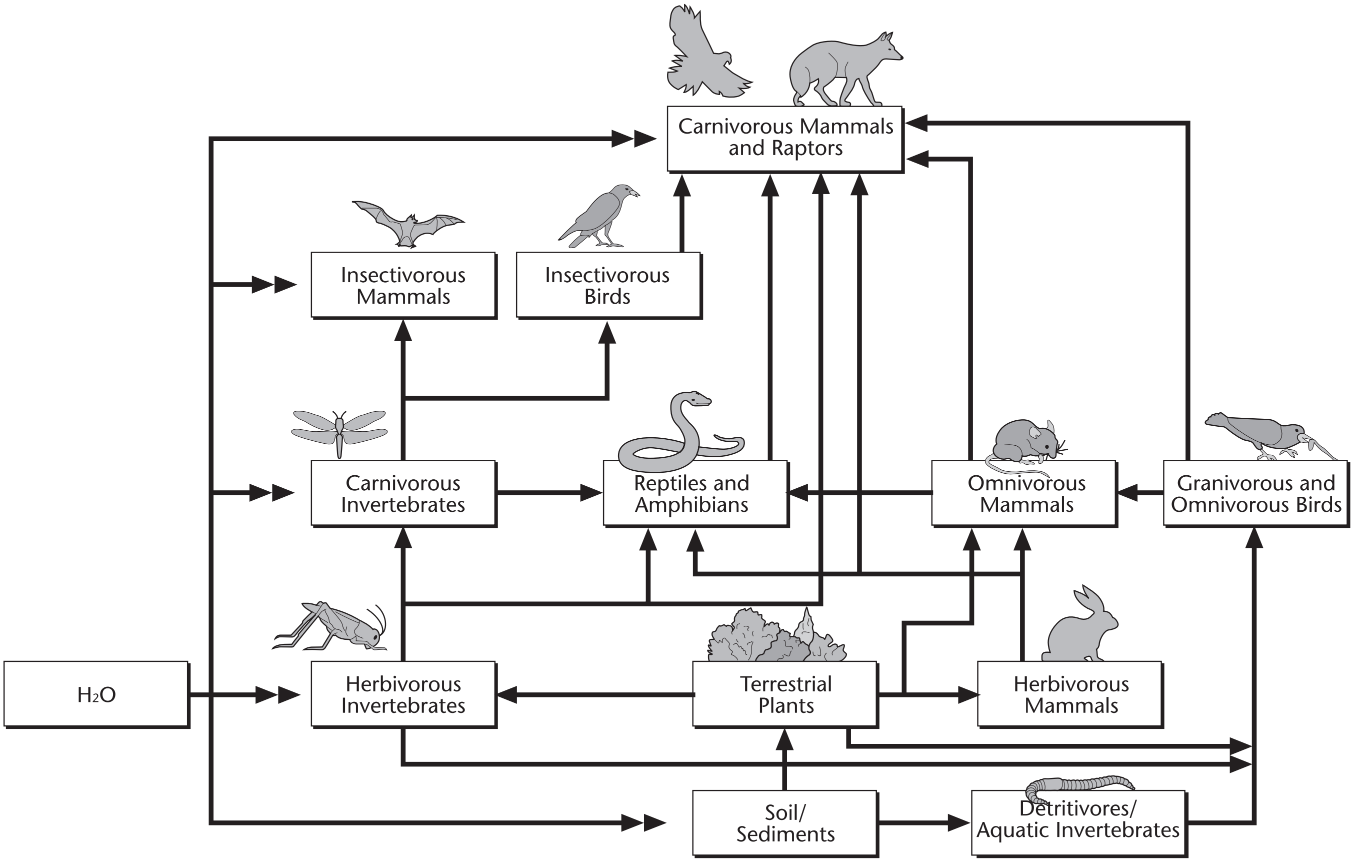

Figure 2. Bio-accumulation of selenium flow-chart for wildlife.

B. Boron

Boron is an essential trace nutrient necessary for plants and animals, as well as for some species of fungi, bacteria and algae. Boron is naturally occurring and is found in varying concentrations in San Joaquin Valley soils and water. There is some evidence that elevated boron may decrease the growth rate of chicks. Also different plant species, including agricultural crops, have different tolerances to boron concentrations in soil and water.

C. Molybdenum

Molybdenum is an essential micronutrient. Evaporation ponds in the southern San Joaquin Valley often contain high concentrations of molybdenum (Ohlendorf and Skorupa, 1993). There is little information about the negative effects of molybdenum on avian and mammalian wildlife.

D. Arsenic

Arsenic is a teratogen (causes deformities) and carcinogen (causes cancer), which can cause fetal death and malformation in many mammal species but may be an essential nutrient in small amounts. High levels of arsenic have been found in the water and sediments of some agricultural subsurface drainage evaporation basins, in the soil, and in underground water tables in the San Joaquin Valley. However, to date, elevated concentrations of arsenic have not been found in wild bird eggs. In addition, some aquatic invertebrate species have been negatively affected by arsenic in the evaporation basins (Ohlendorf and Skorupa, 1993).

E. Salinity and Salt Toxicosis

Evaporation basins are used to collect and dispose of highly saline subsurface drainage water produced in the Tulare Basin, and to a limited extent, on the Westside of the San Joaquin Valley. Aquatic invertebrates, such as brine shrimp, thrive in the hyper-saline water and attract many birds. Waterfowl, particularly the ruddy duck, have been affected by salt encrustation of feathers and salt toxicosis by loafing and feeding in deep hypersaline water evaporation basins. Salt toxicosis (sodium poisoning) generally occurs in times of drought or cool winter temperatures when there is no access to fresh water. The symptoms of salt toxicosis include conjunctivitis (swelling of the eyelids), lens opacity, cataract formation, and vascular congestion in various organs such as the oropharynx (throat), lungs, kidney, and spleen, and most prominently in the meninges of the brain, and myocardial and skeletal muscle degeneration (Gordus et al., 2002). Gordus et al. (2002) found that ambient temperatures below 4°C and hyper-saline water >70,000 mmhos/cm resulted in salt encrustation and salt toxicosis in ruddy ducks.

IV. Water Quality Objectives

Table 1. Water quality objectives for the protection of wildlife. Please note that the following threshold values may change based on future State and Federal regulatory water quality objective requirements. Note: mg/L equals microgram per liter and mg/L equals milligrams per liter.

	Target Water Quality	Water Quality Needs Further Study	Unacceptable
	No Effect	Level of Concern	Toxicity
Selenium (µg/L)[a]	<2	2-5	>5
Arsenic (µg/L)	<5	5-10	>10 [b]
Boron (mg/L)	<0.3	0.3-0.6	>0.6 [c]
Molybdenum (µg/L)	<10	10-19	>19 [b]

[a] Draft Environmental Impact Statement (EIS)/Environmental Impact Report (EIR), Grassland Bypass Project, 2001-2009 (URS 2000).

[b] Preliminary Draft Water Quality Criteria for Refuge Water Supplies Title 34 PL 102-575 Section 3406 (d) 1995. The California Regional Water Quality Board Agriculture Water Quality Objectives for molybdenum is 10 mg/L (A Compilation of Water Quality Goals, Marshack 1998).

[c] Proposed California Regional Water Quality Board Boron and Salinity Objectives for Full Protection of Beneficial Uses in the Lower San Joaquin River at Vernalis. The California Regional Water Quality Board agriculture water quality objective for boron is 0.70 to 0.75 mg/L (A Compilation of Water Quality Goals, Marshack 1998).

V. Biological Sampling

A. Aquatic Invertebrates

Many studies have shown that aquatic invertebrates (insects, snails, worms, etc.), can accumulate high levels of selenium from water and sediment. Sampling and measuring the selenium concentrations of aquatic invertebrates is one of the best indicators for monitoring predator exposures in cases where information is difficult to obtain directly from predator species (Luoma and Presser, 2000). Sampling of aquatic invertebrates may need to be performed if there is standing water that has elevated selenium concentrations, has an established population of invertebrates, and a significant number of birds are observed feeding and using the flooded area.

B. Bird Eggs

Many cases have shown that aquatic birds that feed and nest at subsurface drainage water disposal sites have above normal rates of embryo mortality and teratogenesis and adult mortality, as seen at Kesterson Reservoir (Ohlendorf & Skorupa, 1989).

Collecting bird eggs is the most efficient method for determining selenium impacts to birds that feed and nest at a solar evaporation basin. This is because bird eggs are easy to find and collect, the loss of one egg collected from a nest is not enough to negatively impact a population, embryos are the most sensitive life stage to selenium poisoning, and egg selenium concentrations represent a direct selenium exposure relationship to the adult female over time (Lemly, 1996).

VI. Maintaining a Bird-Free Solar Evaporator

Factors that make solar evaporators attractive or unattractive to birds are:

• Size of the solar evaporator – Larger solar evaporators are more attractive than smaller solar evaporators.

• Location – Is the site within or near a local flyway corridor or wildlife area or refuge? The Valley historically supported extensive wetlands that provided important stop-over foraging and resting habitat for migratory birds. As a result, any artificial "wetlands" that currently occur within the Valley are very attractive to water birds due to the limited wetland acreage remaining.

• Depth of water – Shallow water attracts shore birds and dabbling ducks, and deep water attracts ruddy ducks and eared grebes.

• Standing water – Aquatic invertebrates can become established, which is a food base for water birds.

• Design and management – Certain designs and management techniques enhance the attractiveness of a pond to birds. Avoidance measures to greatly reduce the negative impacts on waterbirds were developed by several researchers in cooperation with DFG and USFWS, (San Joaquin Valley Drainage Program, 1999), (Bradford et al. 1991), (CH2M Hill et al. 1993), (Salmon and March, 1991), (California Department of Water Resources and San Joaquin Valley Drainage Program, 1998).

These measures include:

• Design – Steep banks, flat or level bottoms, no uneven bottoms or high spots, no windbreaks, islands or internal berms present.

• Management – An effective program may reduce the likelihood of a solar evaporator attracting waterbirds to a site.

• Hazing (propane cannons and cracker shells) is one avoidance measure that may be effective in reducing migratory birds foraging and nesting in or around the solar evaporator during the early spring and summer months. Note: Shorebirds and dabbling ducks, such as northern shovelers, mallards and pintails, are easier to haze compared to eared grebes and diving ducks, such as ruddy ducks. Hazing should be discontinued after a nest has become established and eggs have been laid so the nest is not abandoned.

• To prevent aquatic invertebrates from becoming established, do not allow water greater than 1 cm in depth to stand for more than 48 hours.

• Keep dikes, banks and pond bottoms weed free. Manual weed control should not take place during the nesting season unless a qualified wildlife biologist has determined the area to be nest free.

• Appropriate monitoring program should be in place that support an Adaptive Management Program.

Maas-Hoffman Table 1: Salt Tolerance of Herbaceous Crops[1]

Crop		Salt tolerance parameters				References
Common name	**Botanical name‡**	**Tolerance based on:**	**Threshold¶ (Ec_e)**	**Slope dS/m**	**Rating# % per dS/m**	
Fiber, grain, and special crops						
Artichoke, Jerusalem	*Helianthus tuberosus* L.	Tuber yield	0.4	9.6	MS	Newton et al., 1991
Barley††	*Hordeum vulgare* L.	Grain yield	8.0	5.0	T	Ayers et al., 1952 Hassan et al., 1970a
Canola or rapeseed	*Brassica campestris* L. [syn. B. *rapa L.*]	Seed yield	9.7	14	T	Francois, 1994a
Canola or rapeseed	*B. napus* L.	Seed yield	11.0	13	T	Francois, 1994a
Chick pea	*Cicer arietinum* L.	Seed yield	—	—	MS	Manchanda & Sharma, 1989; Ram et al., 1989
Corn§§	*Zea mays* L.	Ear FW	1.7	12	MS	Bernstein & Ayers, 1949b (p. 41-42); Kaddah & Ghowail, 1964
Cotton	*Gossypium hirsutum* L.	Seed cotton yield	7.7	5.2	T	Bernstein, 1955 (p. 37-41), 1956 (p. 33-34); Berntein & Ford, 1959a (p. 34-35).
Crambe	*Crambe abyssinica*	Seed yield	2.0	6.5	MS	Francois & Kleiman, 1990 Hochst. Ex R. E. Fries
Flax	*Linium usitatissimum* L.	Seed yield	1.7	12	MS	Hayward & Spurr, 1944
Guar	*Cyamopsis tetragonoloba* (L.) Taub.	Seed yield	8.8	17	T	Francois et al., 1990
Kenaf	*Hibiscus cannabinus* L.	Stem DW	8.1	11.6	T	Francois et al., 1992
Millet, channel	*Echinochloa turnerana*	Grain yield	—	—	T	Shannon et al., 1981 (Domin) J.M. Black
Oat	*Avena sativa* L.	Grain yield	—	—	T	Mishra & Shitole, 1986; USSL‡‡
Peanut	*Arachis hypogaea* L.	Seed yield	3.2	29	MS	Shalhevet et al., 1969
Rice, paddy	*Oryza sativa* L.	Grain yield	3.0¶¶	12¶¶	S	Ehrler, 1960; Narale et al., 1969; Pearson, 1959; Venkateswarlu et al., 1972
Roselle	*Hibiscus sabdariffa* L.	Stem DW	—	—	MT	El-Saidi & Hawash, 1971
Rye	*Secale cereale* L.	Grain yield	11.4	10.8	T	Francois et al., 1989
Safflower	*Carthamus tinctorius* L.	Seed yield	—	—	MT	Francois & Bernstein, 1964b
Sesame##	*Sesamum indicum* L.	Pod DW	—	—	S	Yousif et al., 1972
Sorghum	*Sorghum bicolor* (L.)	Grain yield	6.8	16	MT	Francois et al., 1984 , Moench
Soybean	*Glycine max* (L.) Merrill	Seed yield	5.0	20	MT	Abel & McKenzie, 1964; Bernstein et al., 1955b (p. 35-36); Bernstein & Ogata, 1966
Sugarbeet†††	*Beta vulgaris* L.	Storage root	7.0	5.9	T	Bower et al., 1954
Sugarcane	*Saccharum officinarum* L.	Shoot DW	1.7	5.9	MS	Bernstein et al., 1966; Dev & Bajwa, 1972; Syed & El-Swaify, 1972
Sunflower	*Helianthus annuus* L.	Seed yield	4.8	5.0	MT	Cheng, 1983; Francois, 1996
Triticale	*X Triticosecale* Wittmack	Grain yield	6.1	2.5	T	Francois et al., 1988
Wheat	*Triticum aestivum* L.	Grain yield	6.0	7.1	MT	Asana & Kale, 1965; Ayers et al., 1952; Hayward & Uhvits, 1944 (p. 41-43)
Wheat (semidwarf) ‡‡‡	*T. Aestivum* L	Grain yield	8.6	3.0	T	Francois et al., 1986
Wheat, Durum	*T. Turgidum* L. var. *durum* Desf.	Grain yield	5.9	3.8	T	Francois et al., 1986

Maas-Hoffman Table 1: Salt Tolerance of Herbaceous Crops[1] *(continued)*

Crop		Salt tolerance parameters				References
Common name	**Botanical name‡**	**Tolerance based on:**	**Threshold¶ (Ec_e)**	**Slope dS/m**	**Rating# % per dS/m**	
Grasses and forage crops						
Alfalfa	*Medicago sativa* L.	Shoot DW	2.0	7.3	MS	Bernstein & Francois, 1973a; Bernstein & Ogata, 1966; Bower et al., 1969; Brown & Hayward, 1956; Gauch & Magistad, 1943; Hoffman et al., 1975
Alkaligrass, Nuttall	*Puccinellia airoideS*	Shoot DW	—	—	T*	USSL staff, 1954 (Nutt.) Wats. & Coult.
Alkali sacaton	*Sporobolus airoides* Torr.	Shoot DW	—	—	T*	USSL staff, 1954
Barley (forage) ††	*Hordeum vulgare* L.	Shoot DW	6.0	7.1	MT	Dregne, 1962; Hassan et al., 1970a
Bentgrass, creeping	*Agrostis stolonifera* L.	Shoot DW	—	—	MS	Younger et al., 1967
Bermudagrass§§§	*Cynodon dactylon* L. Pers.	Shoot DW	6.9	6.4	T	Bernstein & Ford, 1959b (p. 39-44); Bernstein & Francois, 1962 (p. 37- 38); Langdale & Thomas, 1971
Bluestem, Angleton	*Dichanthium aristatum* (Poir.) C.E. Hubb. [syn. *Andropogon nodosus* (Willem.) Nash]	Shoot DW	—	—	MS*	Gausman et al., 1954
Broadbean	*Vicia faba* L.	Shoot DW	1.6	9.6	MS	Ayers & Eberhard, 1960
Brome, mountain	*Bromus marginatus* Nees ex Steud.	Shoot DW	—	—	MT*	USSL staff, 1954
Brome, smooth	*B. inermis* Leyss	Shoot DW	—	—	MT	McElgunn & Lawrence, 1973
Buffellgrass	*Pennisetum ciliare* (L.) Link. [syn. *Cenchrus ciliaris*]	Shoot DW	—	—	MS*	Gausman et al., 1954
Burnet	*Poterium sanguisorba* L.	Shoot DW	—	—	MS*	USSL staff, 1954
Canarygrass, reed	*Phalaris arundinacea* L	Shoot DW	—	—	MT	McElgunn & Lawrence 1973
Clover, alsike	*Trifolium hybridium* L.	Shoot DW	1.5	12	MS	Ayers, 1948a
Clover, Berseem	*T. alexandrinum* L.	Shoot DW	1.5	5.7	MS	Asghar et al., 1962; Ayers & Eberhard, 1958 (p. 36-37); Ravikovitch & Porath, 1967; Ravikovitch & Yoles, 1971
Clover, Hubam	*Melilotus alba* Dest. var. *annua* H. S. Coe	Shoot DW	—	—	MT*	USSL staff, 1954
Clover, ladino	*Trifolium repens* L	Shoot DW	1.5	12	MS	Ayers, 1948a; Gauch & Magistad, 1943
Clover, Persian	*T. resupinatum* L	Shoot DW	—	—	MS*	de Forges, 1970
Clover, red	*T. pratense* L.	Shoot DW	1.5	12	MS	Ayers, 1948a; Saini, 1972
Clover, strawberry	*T. fragiferum* L.	Shoot DW	1.5	12	MS	Ayers, 1948a; Bernstein & Ford, 1959b (p. 39-44); Gauch & Magistad, 1943
Clover, sweet	*Melilotus sp.* Mill.	Shoot DW	—	—	MT*	USSL staff, 1954
Clover, white Dutch	*Trifolium repens* L	Shoot DW	—	—	MS*	USSL staff, 1954
Corn (forage) §§	*Zea mays* L.	Shoot DW	1.8	7.4	MS	Hassan et al., 1970b; Ravikovitch, 1973; Ravikovitch & Porath, 1967
Cowpea (forage)	*Vigna unguiculata* (L.) Walp.	Shoot DW	2.5	11	MS	West & Francois, 1982
Dallisgrass	*Paspalum dilatatum* Poir.	Shoot DW	—	—	MS*	Russell, 1976
Dhaincha	*Sesbania bispinosa* (Linn.) W.F. Wright [syn.	Shoot DW	—	—	MT	Girdhar, 1987; Karadge

Maas-Hoffman Table 1: Salt Tolerance of Herbaceous Crops[1] *(continued)*

Crop		Salt tolerance parameters				References
Common name	**Botanical name**[‡]	**Tolerance based on:**	**Threshold**[¶] **(Ec_e)**	**Slope dS/m**	**Rating**[#] **% per dS/m**	
Grasses and forage crops (con't)						
Fescue, tall	*Festuca elatior* L.	Shoot DW	3.9	5.3	MT	Bower et al., 1970; Brown & Bernstein, 1953 (p. 44-46)
Fescue, meadow	*Festuca pratensis* Huds.	Shoot DW	—	—	MT*	USSL staff, 1954
Foxtail, meadow	*Alopecurus pratensis* L.	Shoot DW	1.5	9.6	MS	Brown and Bernstein, 1953 (p. 44-46)
Glycine	*Neonotonia wightii* [syn. *Glycine wightii* or *javanica*	Shoot DW	—	—	MS	Russell, 1976; Wilson, 1985
Gram, black or Urd bean	*Vigna mungo* (L.) Hepper [syn. *Phaseolus mungo* L.]	Shoot DW	—	—	S	Keating & Fisher, 1985
Grama, blue	*Bouteloua gracilis* (HBK) Lag. Ex Steud.	Shoot DW	—	—	MS*	USSL staff, 1954
Guinea grass	*Panicum maximum* Jacq.	Shoot DW	—	—	MT	Russell, 1976
Hardinggrass	*Phalaris tuberosa* L. var. *stenoptera* (Hack) A.S.	Shoot DW	4.6	7.6	MT	Brown & Bernstein, 1953 (p. 44-46) Hitchc.
Kallargrass	*Leptochloa fusca* (L. Kunth [syn. *Diplachne fusca* Beauv.]	Shoot DW	—	—	T	Sandhu et al., 1981
Lablab bean	*Lablab purpureus* (L.) Sweet [syn. *Dolichos lablab* L.]	Shoot DW	—	—	MS	Russell, 1976
Lovegrass[¶¶¶]	*Eragrostis sp.* N. M. Wolf	Shoot DW	2.0	8.4	MS	Bernstein & Ford, 1959b (p. 39-44)
Milkvetch, Cicer	*Astragalus cicer* L.	Shoot DW	—	—	MS*	USSL staff, 1954
Millet, Foxtail	*Setaria italica* (L.) Beauvois	Dry Matter	—	—	MS	Ravikovitch & Porath, 1967
Oatgrass, tall	*Arrhenatherum elatius* (L.) Beauvois ex J. Presl & K. Presl	Shoot DW	—	—	MS*	USSL staff, 1954
Oat (forage)	*Avena sativa* L.	Straw DW	—	—	T	Mishra & Shitole, 1986; USSL[‡‡]
Orchardgrass	*Dactylis glomerata* L.	Shoot DW	1.5	6.2	MS	Brown & Bernstein, 1953 (p. 44-46); Wadleigh et al., 1951
Panicgrass, blue	*Panicum antidotale* Retz.	Shoot DW	—	—	MS*	Abd El-Rahman et al., 1972; Gausman et al., 1954
Pigeon pea	*Cajanus cajus* (L.) Huth [syn. *C. indicus* (K.) Spreng.]	Shoot DW	—	—	S	Subbaro et al., 1991; Keating & Fisher, 1985
Rape (forage)	*Brassica napus* L.		—	—	MT*	USSL staff, 1954
Rescuegrass	*Bromus unioloides* HBK	Shoot DW	—	—	MT*	USSL staff, 1954
Rhodesgrass	*Chloris Gayana* Kunth.	Shoot DW	—	—	MT	Abd El-Rahman et al., 1972; Gausman et al., 1954
Rye (forage)	*Secale cereale* L.	Shoot DW	7.6	4.9	T	Francois et al., 1989
Ryegrass, Italian	*Lolium multiforum* Lam.	Shoot DW	—	—	MT*	Shimose, 1973
Ryegrass, perennial	*Lolium perenne* L.	Shoot DW	5.6	7.6	MT	Brown & Bernstein, 1953 (p. 44-46)
Ryegrass, Wimmera	*L. Rigidum* Gaud.		—	—	MT*	Malcolm & Smith, 1971
Saltgrass, desert	*Distichlis spicta* L. var. *stricta* (Torr.) Bettle	Shoot DW	—	—	T*	USSL staff, 1954
Sesbania	*Sesbania exaltata* (Raf. V.L. Cory	Shoot DW	2.3	7.0	MS	Bernstein, 1956 (p. 33-34)
Sirato	*Macroptilium atropurpureum* (D.C.) Urb.	Shoot DW	—	—	MS	Russell, 1976

Maas-Hoffman Table 1: Salt Tolerance of Herbaceous Crops[1] *(continued)*

Crop		Salt tolerance parameters				References
Common name	**Botanical name**[‡]	**Tolerance based on:**	**Threshold**[¶] **(Ec_e)**	**Slope dS/m**	**Rating**[#] **% per dS/m**	
Grasses and forage crops (con't)						
Sphaerophysa	*Sphaerophysa salsula* (Pall.) DC	Shoot DW	2.2	7.0	MS	Francois & Bernstein, 1964a (p. 52-53)
Sudangrass	*Sorghum sudanense* (Piper) Stapf	Shoot DW	2.8	4.3	MT	Bower et al., 1970
Timothy	*Phleum pratense* L.	Shoot DW	—	—	MS*	Saini, 1972
Trefoil, big	*Lotus pedunculatus* Cav.	Shoot DW	2.3	19	MS	Ayers, 1948a,b (p. 23-25)
Trefoil, narrowleaf birdsfoot	*L. corniculatus* var *tenuifolium* L.	Shoot DW	5.0	10	MT	Ayers, 1948a, b (p. 23-25)
Trefoil, broadleaf birdsfoot	*L. corniculatus* L. var *arvenis* (Schkuhr) Ser. ex DC	Shoot DW	—	—	MS	Ayers, 1950b (p. 44-45)
Vetch, common	*Vicia angustifolia* L.	Shoot DW	3.0	11	MS	Ravikovitch & Porath, 1967
Wheat (forage)[‡‡‡]	*Triticum aestivum* L.	Shoot DW	4.5	2.6	MT	Francois et al., 1986
Wheat, Durum (forage)	*T. turgidum* L. var. durum Desf.	Shoot DW	2.1	2.5	MT	Francois et al., 1986
Wheatgrass, standard crested	*Agropyron sibiricum*	Shoot DW	3.5	4.0	MT	Bernstein & Ford, 1958 (p. 32-36)
Wheatgrass, fairway crested	*A. cristatum* (L.) Gaertn. (Willd.) Beauvois	Shoot DW	7.5	6.9	T	Bernstein & Ford, 1958 (p. 32-36)
Wheatgrass, intermediate	*A. intermedium* (Host)	Shoot DW	—	—	MT*	Dewey, 1960 Beauvois
Wheatgrass, slender	*A. trachycaulum* (Link) Malte	Shoot DW	—	—	MT	McElgunn & Lawrence, 1973
Wheatgrass, tall	*A. elongatum* (Hort) Beauvois	Shoot DW	7.5	4.2	T	Bernstein & Ford, 1958 (p. 32-36)
Wheatgrass, western	*A. Smithii* Rydb.	Shoot DW	—	—	MT*	USSL staff, 1954
Wildrye, Altai	*Elymus angustus* Trin.	Shoot DW	—	—	T	McElgunn & Lawrence, 1973
Wildrye, beardless	*E. triticoides* Buckl.	Shoot DW	2.7	6.0	MT	Brown & Bernstein, 1953
Wildrye, Canadian	*E. canadensis* L.	Shoot DW	—	—	MT*	USSL staff, 1954
Wildrye, Russian	*E. junceus* Fisch.	Shoot DW	—	—	T	McElgunn & Lawrence, 1973

Maas-Hoffman Table 1: Salt Tolerance of Herbaceous Crops[1] *(continued)*

Crop		Salt tolerance parameters				References
Common name	**Botanical name**[‡]	**Tolerance based on:**	**Threshold**[¶] **(Ec_e)**	**Slope dS/m**	**Rating**[#] **% per dS/m**	
Vegetables and fruit crops						
Artichoke	*Cynara scolymus* L.	Bud yield	6.1	11.5	MT	Francois, 1995
Asparagus	*Asparagus officinalis* L.	Spear yield	4.1	2.0	T	Francois, 1987
Bean, common	*Phaseolus vulgaris* L.	Seed yield	1.0	19	S	Bernstein & Ayers, 1951; Hoffman & Rawlins, 1970; Magistad et al., 1943; Nieman &, 1959; Osawa, 1965
Bean, lima	*P. lunatus* L.	Seed yield	—	—	MT*	Mahmoud et al., 1988
Bean, mung	*Vigna radiate* (L.) R. Wilcz.	Seed yield	1.8	20.7	S	Minhas et al., 1990
Cassava	*Manihot esculenta* Crantz	Tuber yield	—	—	MS	Anonymous, 1976;Hawker & Smith, 1982
Beet, red[†††]	*Beta vulgaris* L.	Storage root	4.0	9.0	MT	Bernstein et al., 1974; Hoffman & Rawlins, 1971; Magistad et al., 1943
Broccoli	*Brassica oleracea* L. (Botrytis group)	Shoot FW	2.8	9.2	MS	Bernstein & Ayers, 1949a (p. 39); Bernstein et al., 1974
Brussel Sprout	*B. oleracea* L. (Gemmifera Group)		—	—	MS*	
Cabbage	*B. oleracea* L. (Capitata Group)	Head FW	1.8	9.7	MS	Bernstein & Ayers, 1949a (p. 39); Bernstein et al., 1974; Osawa, 1965
Carrot	*Daucus carota* L.	Storage root	1.0	14	S	Bernstein & Ayers, 1953a; Bernstein et al., 1974; Lagerwerff & Holland, 1960; Magistad et al., 1943; Osawa, 1965
Cauliflower	*Brassica oleracea* L. (Botrytis Group)		—	—	MS*	
Celery	*Apium graveolens* L. var Dulce (Mill.) Pers.	Petiole FW	1.8	6.2	MS	Francois & West, 1982
Corn, sweet	*Zea mays* L.	Ear FW	1.7	12	MS	Bernstein & Ayers, 1949b (p. 41-42)
Cowpea	*Vigna unguiculata* (L.) Walp.	Seed yield	4.9	12	MT	West & Francois, 1982
Cucumber	*Cucumis sativus* L	Fruit yield	2.5	13	MS	Osawa, 1965; Ploegman & Bierhuizen, 1970
Eggplant	*Solanum melongena* L. var *esculentum* Nees.	Fruit yield	1.1	6.9	MS	Heuer et al., 1986
Garlic	*Allium sativum* L.	Bulb yield	3.9	14.3	MS	Francois, 1994b
Gram, black Or Urd bean	*Vigna mungo* (L.) Hepper [syn. *Phaseolus mungo* L.]	Shoot DW	—	—	S	Keating & Fisher, 1985
Kale	*Brassica oleracea* L. (Acephala Group)		—	—	MS*	Malcolm & Smith, 1971
Kohlrabi	*Brassica oleracea* L (Gongylodes Group)		—	—	MS*	
Lettuce	*Lactuca sativa* L.	Top FW	1.3	13	MS	Ayers et al., 1951; Bernstein et al., 1974; Osawa, 1965
Muskmelon	*Cucumis melo* L. (Reticulatus Group)	Fruit Yield	1.0	8.4	MS	Mangal et al., 1988 Shannon & Francois, 1978
Okra	*Abelmoschus esculentus* (L.) Moench	Pod yield	—	—	MS	Masih et al., 1978; Paliwal & Maliwal, 1972
Onion (bulb)	*Allium cepa* L.	Bulb yield	1.2	16	S	Bernstein & Ayers, 1953b; Bernstein et al., 1974; Hoffman & Rawlins, 1971; Osawa, 1965

Maas-Hoffman Table 1: Salt Tolerance of Herbaceous Crops[1] *(continued)*

Crop		Salt tolerance parameters				References
Common name	**Botanical name**‡	**Tolerance based on:**	**Threshold**¶ **(Ec_e)**	**Slope dS/m**	**Rating**# **% per dS/m**	
Vegetables and fruit crops						
Onion (seed)	*Allium cepa* L	Seed yield	1.0	8.0	MS	Mangal et al., 1989
Parsnip	*Pastinaca sativa* L.		—	—	S*	Malcolm & Smith, 1971
Pea	*Pisium sativum* L.	Seed FW	3.4	10.6	MS	Cerda et al., 1982
Pepper	*Capsicum annuum* L.	Fruit yield	1.5	14	MS	Bernstein, 1954 (p. 36-37); Osawa, 1965, USSL‡‡
Pigeon pea	*Cajanus cajan* (L.) Huth [syn. *C. indicus* (K.) Spreng.]	Shoot DW	—	—	S	Keating & Fisher, 1985; Subbarao et al., 1991
Potato	*Solanum tuberosum* L.	Tuber yield	1.7	12	MS	Bernstein et al., 1951
Pumpkin	*Cucurbita pepo* L var. *Pepo*		—	—	MS*	
Purslane	*Portulaca oleracea* L.	Shoot FW	6.3	9.6	MT	Kumamoto et al., 1992
Radish	*Raphanus sativus* L.	Storage root	1.2	13	MS	Hoffman & Rawlins, 1971; Osawa, 1965
Spinach	*Spinacia oleracea* L.	Top FW	2.0	7.6	MS	Langdale et al., 1971; Osawa, 1965
Squash, scallop	*Cucurbita pepo* L. var *melopepo* L. Alef.	Fruit yield	3.2	16	MS	Francois, 1985
Squash, zucchini	*C. pepo* L. var *melopepo* (L.) Alef.	Fruit yield	4.9	10.5	MT	Francois, 1985; Graifenberg et al., 1996
Strawberry	*Fragaria x ananassa* Duch.	Fruit yield	1.0	33	S	Ehlig & Bernstein, 1958; Osawa, 1965
Sweet potato	*Ipomoea batatas* (L.) Lam.	Fleshy root	1.5	11	MS	Greig & Smith, 1962; USSL‡‡
Tepary bean	*Phaseolus acutifolius* Gray		—	—	MS*	Goertz & Coons, 1991; Hendry, 1918; Perez & Minguez, 1985
Tomato	*Lycopersicon lycopersicum* (L.) Karst. Ex Farw. [syn. *Lycopersicon esculentum* Mill.]]	Fruit yield	2.5	9.9	MS	Bierhuizen & Ploegman, 1967; Hayward & Long, 1943; Lyon, 1941; Shalhevet & Yaron, 1973
Tomato, cherry	*L. lycopersicum* var. *Cerasiforme* (Dunal) Alef.	Fruit yield	1.7	9.1	MS	Caro et al., 1991
Turnip	*Brassica rapa* L. (Rapifera Group)	Storage root	0.9	9.0	MS	Francois, 1984a
Turnip (greens)		Top FW	3.3	4.3	MT	Francois, 1984a
Watermelon	*Citrullus lanatus* (Thunb. Matsum. & Nakai	Fruit yield	—	—	MS*	de Forges, 1970
Winged bean	*Psophocarpus tetragonolobus* L. DC	Shoot DW	—	—	MT	Weil & Khalil, 1986

† These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending upon climate, soil conditions, and cultural practices.
‡ Botanical and common names follow the convention of Hortus Third (Liberty Hyde Bailey Hortorium Staff, 1976) where possible.
§ FW = fresh weight, DW = dry weight.
¶ In gypsiferous soils, plants will tolerate EC_e's about 2dS/m higher than indicated.
# Ratings are defined by the boundaries in Fig. 3-3. (Ratings with an * are estimates.)
†† Less tolerant during seedling stage, EC_e at this stage should not exceed 4 or 5 dS/m.
‡‡ Unpublished U.S. Salinity Laboratory data.
§§ Grain and forage yields of DeKalb XL-75 grown on an organic muck soil decreased about 26% per deciSiemen/meter above athreshold of 1.9 dS/m (Hoffman et al., 1983).
¶¶ Because paddy rice is grown under flooded conditions, values refer to the electrical conductivity of the soil water while the pants are submerged. Less tolerant during seedling stage.
Sesame cultivars, Sesaco 7 and 8, may be more salt tolerant than indicated by the S rating.
††† Sensitive during germination and emergence, EC_e should not exceed 3 dS/m.
‡‡‡ Data from one cultivar, Probred.
§§§ Average of several varities. Suwannee and Coastal are about 20% more tolerant, and common and Greenfield are about 20% less tolerant than the average.
¶¶¶ Average for Boer, Wilman, Sand, and Weeping cultivars (Lehman seems about 50% more tolerant).

Maas-Hoffman Table 2: Salt Tolerance of Woody Crops[2]

Crop		Salt tolerance parameters				References
Common name	**Botanical name‡**	**Tolerance based on:**	**Threshold¶ (Ec_e)**	**Slope dS/m**	**Rating# % per dS/m**	
Almond	*Prunus duclis* (Mill.) D.A. Webb	Shoot growth	1.5	19	S	Bernstein et al., 1956; Brown et al., 1953
Apple	*Malus sylvestris* Mill.		—	—	S	Ivanov, 1970
Apricot	*Prunus armeniaca* L.	Shoot growth	1.6	24	S	Bernstein et al., 1956
Avocado	*Persea americana* Mill.	Shoot growth	—	—	S	Ayers, 1950a; Haas, 1950
Banana	*Musa acuminata* Colla	Fruit yield	—	—	S	Israeli et al., 1986
Blackberry	*Rubus macropetalus* Doug. ex Hook	Fruit yield	1.5	22	S	Ehlig, 1964
Boysenberry	*Rubrus ursinus* Cham. and Schlechtend	Fruit yield	1.5	22	S	Ehlig, 1964
Castorbean	*Ricinus communis* L.		—	—	MS*	USSL staff, 1954
Cherimoya	*Annona cherimola* Mill.	Foliar injury	—	—	S	Cooper et al., 1952
Cherry, sweet	*Prunus avium* L.	Foliar injury	—	—	S*	Beeftink, 1955
Cherry, sand	*Prunus besseyi* L., H. Baley	Foliar injury, stem growth	—	—	S*	Zhemchuzhnikov, 1946
Coconut	*Cocos nucifera* L.		—	—	MT*	Kulkarni et al., 1973
Currant	*Ribes sp*. L	Foliar injury, stem growth	—	—	S*	Beeftink, 1955; Zhemchuzhnikov, 1946
Date palm	*Phoenix dactylifera* L.	Fruit yield	4.0	3.6	T	Furr & Armstrong, 1962; (p. 11-13); Furr & Ream, 1968; Furr et al., 1966
Fig	*Ficus carica* L.	Plant DW	—	—	MT*	Patil & Patil, 1983a; USSL staff, 1954
Gooseberry	*Ribes sp*. L.		—	—	S*	Beeftink, 1955
Grape	*Vitis vinifera* L.	Shoot growth	1.5	9.6	MS	Groot Obbink & Alexander, 1973; Nauriyal & Gupta, 1967; Taha et al., 1972
Grapefruit	*Citrus x paradisi* Macfady.	Fruit yield	1.2	13.5	S	Bielorai et al., 1978
Guava	*Psidium guajava* L.	Shoot and root growth	4.7	9.8	MT	Patil et al., 1984
Guayule	*Parthenium argentatum* A. Gray	Shoot DW rubber yield	8.7 7.8	11.6 10.8	T T	Maas et al., 1988
Jambolan plum	*Syzgium cumini* L.	Shoot growth	—	—	MT	Patil & Patil, 1983b
Jojoba	*Simmondsia chinensis* (Link) C.K. Schneid	Shoot growth	—	—	T	Tal et al., 1979; Yermanos et al., 1967
Jujube, Indian	*Ziziphus mauritiana* Lam.	Fruit yield	—	—	MT	Hooda et al., 1990
Lemon	*Citrus limon* (L.) Burm. F.	Fruit yield	1.5	12.8	S	Cerda et al., 1990
Lime	*Citrus aurantiifolia* (Christm.) Swingle		—	—	S*	
Loquat	*Eriobotrya japonica* (Thunb.) Lindl.	Foliar injury	—	—	S*	Cooper & Link, 1953; Malcolm & Smith, 1971
Macadamia	*Macadamia integrifolia* Maiden & Betche	Seedling growth	—	—	MS*	Hue & McCall, 1989
Mandarin orange;	*Citrus reticulata* Blanco tangerine	Shoot growth	—	—	S*	Minessy et al., 1974
Mango	*Mangifera indica* L.	Foliar injur	—	—	S	Cooper et al., 1952

Maas-Hoffman Table 2: Salt Tolerance of Woody Crops[2] *(continued)*

Crop		Salt tolerance parameters				References
Common name	**Botanical name‡**	**Tolerance based on:**	**Threshold¶ (Ec_e)**	**Slope dS/m**	**Rating# % per dS/m**	
Natal plum	*Carissa grandiflora* (E.H. Mey.) A. DC.	Shoot growth	—	—	T	Bernstein et al., 1972
Olive	*Olea europaea* L. fruit yield	Seedling growth,	—	—	MT	Bidner-Barhava & Ramati, 1967; Taha et al., 1972
Orange	*Citrus sinensis* (L.) Osbeck	Fruit yield	1.3	13.1	S	Bielorai et al., 1988; Bingham et al., 1974; Dasberg et al., 1991; Harding et al., 1958
Papaya	*Carica papaya* L.	Seedling growth, foliar injury	—	—	MS	Kottenmeier et al., 1983; Makhija & Jindal, 1983
Passion fruit	*Passiflora edulis* Sims.		—	—	S*	Malcolm & Smith, 1971
Peach	*Prunus persica* (L.) Batsch	Shoot growth, fruit yield	1.7	21	S	Bernstein et al., 1956 Brown et al., 1953; Hayward et al., 1946
Pear	*Pyrus communis* L.		—	—	S*	USSL staff, 1954
Pecan	*Carya illinoinensis* (Wangeth) C. Koch	Nut yield trunk growth	—	—	MS	Miyamoto et al., 1986
Persimmon	*Diospyros virginiana* L.		—	—	S*	Malcolm & Smith, 1971
Pineapple	*Ananas comosus* (L.) Merrill	Shoot DW	—	—	MT	Wambiji & El-Swaify, 1974
Pistachio	*Pistachia vera* L.	Shoot growth	—	—	MS	Sepaskhah & Maftoun, 1988; Picchioni et al., 1990
Plum; prune	*Prunus domestica* L.	Fruit yield	2.6	31	MS	Hoffman et al., 1989
Pomegranate	*Punica granatum* L.	Shoot growth	—	—	MS	Patil & Patil, 1982
Popinac, white	*Leucaena leucocephala* (Lam.) De Wit [syn. *Leucaena glauca* Benth.]	Shoot DW	—	—	MS	Gorham et al., 1988; Hansen & Munns, 1988
Pummelo	*Citrus maxima* (Burm.)	Foliar injury	—	—	S*	Furr & Ream, 1969
Raspberry	*Rubus idaeus* L.	Fruit yield	—	—	S	Ehlig, 1964
Rose apple	*Syzgium jambos* (L.) Alston	Foliar injur	—	—	S*	Cooper & Gorton, 1951 (p. 32-38)
Sapote, white	*Casimiroa edulis* Llave	Foliar injur	—	—	S*	Cooper et al., 1952
Scarlet wisteria	*Sesbania grandiflora*	Shoot DW	—	—	MT	Chavan & Karadge, 1986
Tamarugo	*Prosopis tamarugo* Phil.	Observation	—	—	T	Natl. Acad. Sci., 1975
Walnut	*Juglans* spp.	Foliar injury	—	—	S*	Beeftink, 1955

† These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending upon climate, soil conditions, and cultural practices. The data are applicable when rootstocks are used that do not accumulate Na^+ or Cl^- rapidly or when these ions do not predominate in the soil.

‡ Botanical and common names follow the convention of Hortus Third (Liberty Hyde Bailey Hortorium Staff, 1976) where possible.

§ In gypsiferous soils, plants will tolerate EC_e's about 2 dS/m higher than indicated.

¶ Ratings are defined by the boundaries in Fig. 3-3. Ratings with an * are estimates.

Maas-Hoffman Table 3: Boron Tolerance Limits for Agricultural Crops

Crop		Boron tolerance parameters				References
Common name	Botanical name	Tolerance[†] based on:	Threshold[‡] g m-3	Slope % per g m-3	Rating[§]	
Alfalfa	*Medicago sativa* L.	Shoot DW	4.0-6.0		T	Eaton, 1944
Apricot	*Prunus armeniaca* L.	Leaf & stem injury	0.5-0.75		S	Woodbridge, 1955
Artichoke, globe	*Cynara scolymus* L.	Laminae DW	2.0-4.0		MT	Eaton, 1944
Artichoke, Jerusalem	*Helianthus tuberosus* L.	Whole plant DW	0.75-1.0		S	Eaton, 1944
Asparagus	*Asparagus officinalis* L.	Shoot DW	10.0-15.0		VT	Eaton, 1944
Avocado	*Persea americana* Mill.	Foliar injury	0.5-0.75		S	Haas, 1929
Barley	*Hordeum vulgare* L.	Grain yield	3.4	4.4	MT	Bingham et al., 1985
Bean, kidney	*Phaseolus vulgaris* L.	Whole plant DW	0.75-1.0		S	Eaton, 1944
Bean, lima	*Phaseolus lunatus* L.	Whole plant DW	0.75-1.0		S	Eaton, 1944
Bean, mung	*Vigna radiata* L. R. Wilcz.	Shoot length	0.75-1.0		S	Khundairi, 1961
Bean, snap	*Phaseolus vulgaris* L.	Pod yield	1.0	12	S	Francois, 1989
Beet, red	*Beta vulgaris* L.	Root DW	4.0-6.0		T	Eaton, 1944
Blackberry	*Rubus sp.* L	Whole plant DW	<0.5		VS	Eaton, 1944
Bluegrass, Kentucky	*Poa pratensis* L.	Leaf DW	2.0-4.0		MT	Eaton, 1944
Broccoli	*Brassica oleracea* L. (Botrytis group)	Head FW	1.0	1.8	MS	Francois, 1986
Cabbage	*Brassica oleracea* L. (Capitata group)	Whole plant DW	2.0-4.0		MT	Eaton, 1944
Carrot	*Daucus carota* L.	Root DW	1.0-2.0		MS	Eaton, 1944
Cauliflower	*Brassica oleracea* L. (Botrytis group)	Curd FW	4.0	1.9	MT	Francois, 1986
Celery	*Apium graveolens* L. var. dulce (Mill.) Pers.	Petiole FW	9.8	3.2	VT	Francios, 1988
Cherry	*Prunus avium* L.	Whole plant DW	0.5-0.75		S	Eaton, 1944
Clover, sweet	*Melilotus indica* All.	Whole plant DW	2.0-4.0		MT	Eaton, 1944
Corn	*Zea mays* L.	Shoot DW	2.0-4.0		MT	El-Sheikh et al., 1971
Cotton	*Gossypium hirsutum* L.	Boll DW	6.0-10.0		VT	Eaton, 1944
Cowpea	*Vigna unguiculata* (L.) Walp.	Seed yield	2.5	12	MT	Francois, 1989
Cucumber	*Cucumis sativus* L.	Shoot DW	1.0-2.0		MS	El-Sheikh et al., 1971
Fig, kadota	*Ficus carica* L.	Whole plant DW	0.5-0.75		S	Eaton, 1944
Garlic	*Allium sativum* L.	Bulb yield	4.3	2.7	T	Francois, 1991
Grape	*Vitis vinifera* L.	Whole plant DW	0.5-0.75		S	Eaton, 1944
Grapefruit	*Citrus x paradisi* Macfady.	Foliar injury	0.5-0.75		S	Haas, 1929
Lemon	*Citrus limon* (L.) Burm. f.	Foliar injury, plant DW	<0.5		VS	Eaton, 1944; Haas, 1929
Lettuce	*Lactuca sativa* L.	Head FW	1.3	1.7	MS	Francois, 1988
Lupine	*Lupinus hartwegii* Lindl.	Whole plant DW	0.75-1.0	S		Eaton, 1944
Muskmelon	*Cucumis melo* L. (Reticulatus group)	Shoot DW	2.0-4.0		MT	Eaton, 1944; El- Sheikh et al.,1971
Mustard	*Brassica juncea* Coss.	Whole plant DW	2.0-4.0		MT	Eaton, 1944
Oat	*Avena sativa* L.	Grain (immature) DW	2.0-4.0		MT	Eaton, 1944
Onion	*Allium cepa* L.	Bulb yield	8.9	1.9	VT	Francois, 1991
Orange	*Citrus sinensis* (L.) Osbeck	Foliar injury	0.5-0.75		S	Haas, 1929
Parsley	*Petroselinum crispum* Nym.	Whole plant DW	4.0-6.0		T	Eaton, 1944
Pea	*Pisum sativa* L.	Whole plant DW	1.0-2.0		MS	Eaton, 1944
Peach	*Prunus persica* (L.) Batsch.	Whole plant DW	0.5-0.75		S	Eaton, 1944; Haas, 1929

Maas-Hoffman Table 3: Boron Tolerance Limits for Agricultural Crops *(continued)*

Crop		Boron tolerance parameters				References
Common name	Botanical name	Tolerance† based on:	Threshold‡ g m-3	Slope % per g m-3	Rating§	
Peanut	*Arachis hypogaea* L.	Seed yield	0.75-1.0		S	Gopal, 1971
Pecan	*Carya illinoinensis* (Wangenh.) C. Koch	Foliar injury	0.5-0.75		S	Haas, 1929
Pepper, red	*Capsicum annuum* L.	Fruit yield	1.0-2.		MS	Eaton, 1944
Persimmon	*Diospyros kaki* L.f.	Whole plant DW	0.5-0.75		S	Eaton, 1944
Plum	*Prunus domestica* L.	Leaf & stem injury	0.5-0.75		S	Woodbridge, 1955
Potato	*Solanum tuberosum* L.	Tuber DW	1.0-2.0		MS	Eaton, 1944
Radish	*Raphanus sativus* L.	Root FW	1.0	1.4	MS	Francois, 1986
Sesame	*Sesamum indicum* L.	Foliar injury	0.75-1.0		S	Khundairi, 1961
Sorghum	*Sorghum bicolor* (L.)	Grain yield	7.4	4.7	VT	Bingham et al., Moench 1985
Squash, scallop	*Curcurbita pepo* L. *var melopepo* (L.) Alef.	Fruit yield	4.9	9.	T	Francois, 1992
Squash, winter	*Curcurbita moschata Poir*	Fruit yield	1.0	4.3	MS	Francois, 1992
Squash, zucchini	*Curcurbita pepo* L. *var melopepo* L. Alef.	Fruit yield	2.7	5.2	MT	Francois, 1992
Strawberry	*Fragaria sp.* L.	Whole plant DW	0.75-1.0		S	Eaton, 1944
Sugar beet	*Beta vulgaris* L.	Storage root FW	4.9	4.1	T	Vlamis & Ulrich, 1973
Sunflower	*Helianthus annuus* L.	Seed yield	0.75-1.0		S	Pathak et al., 1975
Sweet potato	*Ipomoea batatas* (L.) Lam.	Root DW	0.75-1.0		S	Eaton, 1944
Tobacco	*Nicotiana tobacum* L.	Laminae DW	2.0-4.0		MT	Eaton, 1944
Tomato	*Lycopersicon lycopersicum* (L.) Karst. ex Farw.	Fruit yield	5.7	3.4	T	Francois, 1984b
Turnip	*Brassica rapa* L. (Rapifera	Root DW group)	2.0-4.0		MT	Eaton, 1944
Vetch, purple	*Vicia benghalensis* L.	Whole plant DW	4.0-6.0		T	Eaton, 1944
Walnut	*Juglans regia* L.	Foliar injury	0.5-0.75		S	Haas, 1929
Wheat	*Triticum aestivum* L.	Grain yield	0.75-1.0	3.3	S	Bingham et al., 1985; Khundairi, 1961

† FW = fresh weight, DW = dry weight.

‡ Maximum permissible concentration in soil water without yield reduction. Boron tolerances vary, depending upon climate, soil conditions, and crop varieties.

§ The B tolerance ratings are based on the following threshold concentration ranges: <0.5 g m^{-3} very sensitive (VS), 0.5 to 1.0 g m^{-3} sensitive (S), 1.0 to 2.0 g m^{-3} moderately sensitive (MS), 2.0 to 4.0 g m^{-3} moderately tolerant (MT), 4.0 to 6.0 g m^{-3} tolerant (T), and >6.0 g m^{-3} very tolerant (VT).

Summary of forage performance under IFDM management at Red Rock Ranch

Benes et al., 2005* and **Suyama** et al., 2005**

All forages were irrigated with saline drainage water, except alfalfa which was irrigated with either freshwater or a DW blend. Data are averages for Fall 2002 to 2004.

Forages†	Field	DW irrigation (yrs.)	ECw (dS/m)	ECe (dS/m)	Soil Boron (mg/kg)	SAR	BM Production (MT/ha/yr)††	Forage Quality††† ME (MJ/kg DM)	CP (%)	NDF (%)	Ash (%)	Se (mg/kg)
Tall Wheatgrass	1	5	7.2	19.1	25.1	38.0	7.1	9.32	15.6	56.5	9.7	6.12
Tall Wheatgrass	2	5	9.8	17.6	23.0	35.3	6.8	9.22	11.3	62.1	8.0	7.38
Creeping wildrye	1	2	8.6	13.3	18.7	29.4	10.6	8.24	16.4	60.9	8.7	2.98
Creeping wildrye	2	5	9.8	12.9	18.7	28.1	12.3	7.91	13.9	65.1	8.1	10.72
Puccinellia	1	5	9.8	15.0	23.2	29.9	5.5	9.56	17.7	60.4	8.8	4.37
Tall fescue	1	5	9.8	12.1	16.8	27.3	4.5	9.32	19.0	54.4	11.5	7.41
Alkali sacaton	1	5	9.8	12.4	15.8	26.7	6.7	6.72	12.1	72.2	9.3	6.88
Alfalfa/DW	1	1	6.7	6.9	7.1	17.5	16.7	9.62	23.7	37.5	9.9	1.45
Alfalfa/FW	2	0	1.1	4.7	3.6	12.2	19.1	9.85	24.8	34.8	10.3	0.80

† Tall wheatgrass var. 'Jose', Creeping wild rye var. 'Rio', Puccinellia ciliata, Tall fescue var. 'Alta', Alkali sacaton ('solado'), and Alfalfa vars. 'salado' & '801S' (50:50 mix) irrigated either with drainage water (DW) or fresh water (FW).

†† Metric tons dry matter per hectare per year.

††† Forage quality parameters include: metabolizable energy (ME), crude protein (CP), neutral detergent fiber (NDF) and ash.

*Benes S., Suyama H., Robinson P., Getachew G., Grattan S.R., and C. Grieve (2005). Forages Growing in Saline Drainage Water Re-use Systems on the Westside San Joaquin Valley of California: water use, productivity, and nutritional value. Proceedings of the International Salinity Forum: Managing Saline Soils and Water: Science, Technology, and Management. April 25-27, 2005. Riverside, CA. Oral Presentation Abstracts, pp. 55-58.

**Suyama H., Benes S., Robinson P., Getachew G., Grattan S.R., and C. Grieve (2005). Biomass Production and Nutritional Value of Forages Irrigated with Saline-sodic Drainage Water in a Greenhouse Study. Proceedings of the International Salinity Forum: Managing Saline Soils and Water: Science, Technology, and Management. April 25-27, 2005. Riverside, CA. Poster Abstracts, pp. 175-178.

Sources for Plant Materials

Government – Forages or Halophytes

1. USDA Plant Materials Center (PMC), Lockeford California. (209) 727-5319.

2. Westside Resource Conservation District (WSRCD). (559) 227-2489.

Commercial* – Salt Tolerant Forages

1. America's Alfalfa. Tel: (800) 873-2532. Material: 'Salado' and 'Ameristand 801S' salt tolerant alfalfa.

2. K-F Seeds. 4307 Fifield Road. Brawley, CA 92227. Tel: (760) 344-6391, FAX: (760) 344- 6394. Materials: Bermudagrass seed. Varieties 'Giant' and 'Common'.
   'Tifton' is also recommended, but may not be available from this company.

3. S&W Seed Co. P.O. Box 235, Five Points, CA 93624. Tel: (559) 884-2535 swseedco@pacbell.net. Web: www.swseedco.com.
   Materials: "Westside Wheatgrass", a commercialized variety of 'Jose' Tall Wheatgrass and 'SW 9720' Salt tolerant alfalfa.

4. West Coast Turf. PO Box 4563, Palm Desert, CA 92261. Tel: (800) 447-1840, (760) 346-TURF, and FAX: (760) 360-5616. Material: Seashore Paspalum ('SeasIsle 1') sod or chopped stolons.

Commercial* – Halophytes

1. NyPa International. Dr. Nick Yensen. 727 N. Ninth Ave., Tucson, Arizona 85705. Tel: (520) 624-7245, FAX: (520) 908-0819, email: nypa@aol.com. Web: http://expage.com/nypa.
   Materials: "NyPa forage", a commercialized saltgrass (Distichlis spicata).
   Tulare Lake Drainage District, Corcoran, CA. Tel: (559) 992-3145 may also be contacted to obtain NyPa forage.

2. Saline Seed, Inc. Contact: Mr. Daniel Murphy, 1900 Mountain Valley Lane Escondido, California 92029. Tel: (760) 294-3079, Fax: (760) 294-3081, e-mail: danielmurphyusa@yahoo.com. Web: http://salicornia.com/
   Materials: Salicornia and other halophytes and salt tolerant forages.

*List is not inclusive and does not represent an endorsement of these companies.

CA Department of Water Resources Agroforestry Database Description

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United States Department of Agriculture-Natural Resources Conservation Service (retired)

The California Department of Water Resources, San Joaquin District , has developed a database for trees, shrubs and herbacous species planted on drainage-impacted areas in the western and southern parts of the San Joaquin Valley. This database includes a set of GIS layers showing mapped locations of these plots, along with purpose of planting, date of planting, street locations, county, partnerships, species planted, water and/or soil quality data if available, etc., contained in associated GIS tabular data.

These data also are contained in Excel spreadsheets (see Appendix CD). The intent of the Department is that these data, including GIS, will be available on the Internet, in order to facilitate planning for water table interception, recycling drainage water or harvest in drainage-impacted areas. A searchable database containing all known documents related to drainage issues, also is planned to be a significant part of the Web-based information.

IFDM Plant Management Guide

Clarence Finch & Frank Menezes
With revisions by **Sharon Benes** *and* **Vashek Cervinka** *(12-2003)*

Salt-tolerant Grasses and Halophytes

This guide uses the term "salt-tolerant grasses" for plants tolerating drainage water of EC from 8 to 15 dS/m, and the term "halophytes" for plants tolerating drainage water above EC 15 dS/m. Using water salinity of EC 15 as a separating limit is rather artificial, but it can be said that halophytes tolerate higher salinity than salt-tolerant grasses.

This selection of forages, halophytes, and trees for saline drainage management for the Westside San Joaquin Valley was based on literature review from the USA, Australia, Israel, and other countries, field evaluation trials, and a survey of salt-tolerant plants in semi-arid world regions. The set of plants used in both areas is the result of a multiple-year selection process. These plants are being selected not only for salt management purposes, but also for their biological interaction with conventional farm crops to avoid introducing species that could be potential weeds or host plants for insect vectors of plant viruses.

Salt-tolerant grasses and halophytes should preferably be perennial plants to manage higher flows of drainage water during the winter/spring period. The other required characteristics include high water demand, tolerance to frequent flooding, frost tolerance, and marketability of harvested biomass. Salt-tolerant grasses and halophytes should preferably be mainly used for the re-use of drainage water so as to reduce its volume. They are grown on a relatively small area of the farm (2%-8%). Trees are most commonly used in strips to intercept subsurface lateral flows of groundwater and/or to locally drop the water table. Commercial value is of primary importance for the areas under irrigation with freshwater or low salinity water where vegetables and salttolerant field crops (cotton, wheat, canola, sugar beets, and possibly, alfalfa) are grown. However, economic value can be a secondary consideration in the selection of salt-tolerant grasses, halophytes, and trees.

Recommended plant management

Prepare soil by leveling the planting area to achieve uniform water distribution in the fields of salt-tolerant grasses and halophytes. This is essential for plant growth and salt leaching, as well as for minimizing water ponding that could potentially attract wildlife. When establishing the plants in an area with slope, divide this the area into blocks by throwing up borders (ridges of soil) to confine the water and level each block for uniform water distribution. If an area is too steep to level to a uniform grade for irrigation and leaching, use sprinklers to irrigate. Good stands require weed-free soil conditions.

Establish plants by seeding or by planting rooted plants (plugs). Use a drill on a "vegetable type" seedbed or on a seedbed prepared with a corrugated roller. Broadcast seed on a leveled, disked corrugated surface of shallow furrow (such as tomato beds). It is recommended to plant plugs in the bottom of the rills (furrows). This reduces the salt load around the base of the plants and allows water to reach the plants more quickly. Alternatively, in a raised bed system, the seed or cuttings should be placed on the edges of the bed, avoiding the center of the bed which is the zone of maximum salt accumulation.

There are a number of methods for planting rooted plants such as by shovel, dibble, or by a mechanical vegetable planter. The most successful method is either the tree planter or the vegetable planter because they open up the soil, and the plant is placed deeper in the soil. Timing of planting is very important. Cool season grasses should be planted in the fall. Warm season plants in the spring.

When planting rooted plants, irrigation should follow as soon as possible after planting. Fresh water (less than 3 dS/m) should be used to irrigate until salt-tolerant plants are well established. Some perennials have to be planted and established for about a year before applying water over 10 dS/m. Salicornia and other halophytes may require saline water to be established. Once plants are established, border (flood) irrigation is recommended to effectively leach salts. Sprinklers are also effective for leaching salts below the root zone and/or on land that is too steep to flood. Irrigation frequency depends on plant, soil, and climatological conditions. Cycles of watering and drying are important. Yellowing of plants may be caused by overwatering or salt build-up.

Mowing helps to control weeds. Mowing height can be critical to plant survival. The following are the recommended mowing heights for plants:

- Bermudagrass and Saltgrass 10 cm (4 inches)
- Tall Wheatgrass, Alkali Sacaton, Beardless wildrye, 20 to 25 cm (8 to 10 inches) and Cordgrass
- Atriplex and Allenrolfea 25 to 50 cm (10 to 20 inches)
- Harvest salt-tolerant grasses and halophytes for hay or seeds. Grazing can be a preferable method of management. Do not graze when soils are wet, as compaction will reduce water infiltration.

Salt-Tolerant Grasses and Halophytes

(Brief Description)

Jose Tall Wheatgrass (Elytrigia elongata) (Agropyron elongatum)

Tall wheatgrass is a tall growing, erect, late maturing, perennial bunch grass. Plants range from 60 to 150 cm (2 to 5 feet) tall and the grass produces large erect seed heads that develop a good crop of seed. Growth starts in the spring and continues into late summer. The plant can be established in the fall by broadcast or drill, on a weed-free firm seedbed. Good stands can be established on saline-alkali sites by planting in bottoms of furrows and irrigating every 4 to 5 days until the seedlings have emerged to a height of 10 to 15 cm (4 to 6 inches). Established plants have been growing in soils with up to ECe of about 25 dS/m. It can be irrigated with drainage water of EC ranging from 8 to 13 dS/m. Tall wheatgrass is utilized by all kinds of livestock as pasture, hay or silage. It is important to maintain a stubble height of 20 cm (8 inches) when cutting for hay, silage or mowing down old seed head growth. This plant is excellent habitat for wildlife providing safe escape and excellent nesting cover, especially for pheasants.

Jose Tall Wheatgrass

Creeping wildrye ('Rio'), also called Beardless wildrye (Leymus triticoides or Elymus triticoides).

Creeping wildrye is a native perennial grass 60 to 150 cm (2 to 5 feet) tall growing singly or in small clumps. Due to its scaly underground rhizomes, it often spreads over large areas. While most native stands do not produce viable seed, the 'Rio' selection consistently produces viable seed. The plant can be established by seed in the fall, also by the underground rhizomes or by container grown plants. Established plants of creeping wildrye have been growing with EC 10 to 12 dS/m drain water. This forage is eaten by cattle and sheep and is excellent escape and nesting cover for wildlife.

Alkali Sacaton ('Salado') (Sporobolus airoides)

Alkali sacaton is a warm season native perennial bunchgrass. Plants range from 60 to 75 cm (2 to 2.5 feet) tall with curving leaves. Seed heads form a widely spreading panicle nearly onehalf the entire height of the plant. Plants may be 20 to 30 cm (8 to 12 inches) in diameter at ground level. The plant is established in the spring by seed or container-grown plants. Due to small seed, a good firm moist seedbed is required. Established plants have been growing with EC of 10 to 14 dS/m drain water. Alkali sacaton is good forage for cattle and horses and fair for sheep. This forage is sometimes called "salado," which should not be confused with a new salt tolerant variety of alfalfa, also called "salado".

Koleagrass ('Perla') (Phalaris tuberosa var. hirtiglumis)

Koleagrass is a tall, robust, rapid developing perennial bunchgrass. Plants range from 60 to 150 cm (2 to 5 feet) tall with short stout rhizomes originating from the base. Perla is established in the fall by seeding on a firm, weed free seedbed, or by container-grown plants. Established plants have been growing with EC of 10 to 12 dS/m drain water. Perlagrass is a very palatable grass relished by all kinds of livestock. It starts growth in the fall with moisture and continues to grow into the winter months. Due to this growth habit the plant supplies fall and winter feed for livestock and excellent cover for wildlife, especially pheasants.

Tall Fescue ('Alta' and 'Goar') (Festuca arundinacea)

Tall Fescue is an aggressive, erect, deeply rooted perennial bunch grass. The plant is from 60 to 100 cm (2 to 3 feet) tall and produces heavy sod and fibrous root material. Growth starts in the spring and continues into late winter. The plant is established in the fall from seeds by broadcast or drill on a weed-free firm seedbed. Once established, it can be irrigated with drainage water of EC 8 to 12 dS/m. Tall fescue is utilized by all kinds of livestock as pasture or hay. It is an excellent shade and nesting cover for wildlife.

Creeping Wildrye

Alkali Sacaton

Bermuda grass

Bermuda grass is a perennial crop that is moderately salt tolerant, and drought resistant. It is established by seed and spreads by rhizomes. Bermuda grass forms dense turf and can be grazed or cut for hay harvesting.

Halophytes

Pickleweed ('Samphire') (Salicornia bigelovii)

Pickleweed is a low growing very succulent annual plant that is 15 to 38 cm (6 to 15 inches) tall with green scale-like leaves. The plant is established from seed by broadcast or drilling on a well- prepared firm seedbed, similar to establishing alfalfa stands. In fact, the seed is similar in size to alfalfa. Seeding is recommended after the frost period in the spring; however in the SJV, seed can be applied in the late fall / early winter: it will lie dormant and germinate in about March. The stand can be flood or sprinkler irrigated. The plant requires salty water of EC 20 to 30 dS/m. Surface soil in this stand may have an ECe as high as 50 dS/m. Salicornia can be irrigated with lower EC water, provided that the soil salinity is considerably higher than 20 dS/m; however, its growth and seed production will be less. Pickleweed may have multiple uses. One of its main uses is for seed production. When processed it produces oil which contains polyunsaturated fat close to the level of safflower oil and better than soybean oil. The meal from the oil processing can be used as a feed source for poultry and livestock. The young top portions of the plant are used as a salad green and a tasty vegetable in areas of the world where it is irrigated with brackish water or with seawater.

Saltgrass (Distichlis spicata)

Saltgrass is a gray green to blue green, perennial grass with strong extensively creeping rhizomes. The mature plant can grow to 45 cm (18 inches) tall. The plant can be established by seed. The most common method of establishment is from rhizomes. Rhizomes can be single or chunks of sod. Plants establish much faster from sod. Spring establishment is the most desirable. Established plants have been growing in soils with an ECe of 30 dS/m. In its natural state plants are commonly found on roadsides, ditch banks and along salt marshes adjacent to coastal tidal marsh areas. The plant is grazed by livestock.

Cordgrass (Spartina species)

A perennial bunch-like, coarse-textured grass 30 to 100 cm (1 to 3 feet) tall and up to 30 to 75 cm (1 to 2.5 feet) thick at the base. Some plants have extensive creeping rhizomes. The plant can be established from rooted cuttings that were grown in plastic cone containers. Planting stock is taken from a clump of a mature plant and the small base of the plant is rooted in cone containers. Rooted plants can be established at any time of the year, but the best time is during the fall and spring. Cordgrass has been grown with drainage water with an EC of up to 35 dS/m. In its natural state, plants are growing in salt marshes and tidal flats. On the Atlantic coast, marsh hay consisting of mostly cordgrass is used for packing or bedding. The species of cordgrass grown are (Spartina alternaflora and Spartina gracilia) and 2 accessions of (Spartina patens) named 'Flageo' and 'Avalon' that has rhizomes.

Iodine bush (Allenrolfea occidentalis)

Iodine bush is an erect bush 30 to 180 cm (1 to 6 feet) tall, multiple branched. The green foliage is somewhat fleshy, with scale-like leaves. Establishment can be from seed or containergrown plants. Seed can be planted by broadcast or drill in late winter. Plantings in the fall can be made by seed, but weed competition at this time makes stand establishment difficult. Due to very small seed, the plants have very weak seedling vigor and a firm, weed-free condition must prevail during establishment. Container-grown plants can be established in the fall or spring. Seed can be easily harvested from native stands in the early winter. Established plants have been growing in soils with up ECe of 60 dS/m and with water of EC 30 dS/m. In its natural state, livestock have grazed the plant and have eliminated stands in dryland pastures when other vegetation has been used up. Its use in feed supplements has not been investigated extensively.

Iodine Bush

Saltbush (Atriplex species)

Atriplex is an erect spreading perennial shrub with dense foliage. It ranges from 2 to 6 feet in height and in width. Seed maturity is from October to December. The plant can be established from seed, bare-root or container-grown plants. Seed can be planted by broadcast or drill in late winter, January through March. A good firm seedbed is required. Broadcast seeding may appear inadequate the first year, but small plants at the end of the first year produce strong plants the second year. The best way to establish this shrub is from container-grown plants. Transplanting can be done in fall or spring. Established plants tolerate drainage water EC ranging from 28 to 30 dS/m. Livestock use Atriplex as browse or as a feed supplement, especially when fed in selenium deficient areas. In its natural state it provides excellent cover for upland game and rabbits. Atriplex can be a host for the sugar beet leafhopper, which may carry a virus that causes a curly top disease in sugar beets, and in vegetable crops like tomatoes, beans, and cantaloupe. Some of the Atriplex species used are A. lentiformis and A. nummularia.

Saltbush

Trees

Trees use and evaporate drainage water. This is achieved through the sequential reuse, by intercepting the flow of drainage water from upslope, or through the uptake of shallow groundwater. Trees can be viewed as biological pumps.

The role of Eucalyptus trees is to lower water tables and to occasionally receive reused drainage water, and thus, to assist in reducing the volume of drainage water to be managed.

Eucalyptus

Eucalyptus camaldulensis, River Red Gum, has been the superior tree selected and is now propagated as clones by a nursery in Southern California. The best Eucalyptus clones are 4573, 4543, and 4544. These are identification numbers assigned to selected trees by the Eucalyptus Improvement Association.

Both salt-tolerant plants and trees use drainage water and reduce its volume. The trees take up saline groundwater to lower water tables, intercept sub-surface water flows, sequentially reuse drainage water, and create a biological barrier between low-saline and high-saline areas. Drainage water is mainly applied to salt-tolerant plants and only occasionally to the trees (e.g., during high flows of drainage water).

Planting and care of trees

Three methods of planting trees to reduce saline conditions on cropland are used. The trees intercept subsurface water flow, consume groundwater to lower water tables, and sequentially reuse drainage water. The tree blocks also serve as windbreaks, buffer strips, filter strips, and reduce dust problems.

The planting area should be leveled to avoid water ponding. Standing water can damage the trees and could become a potential environmental concern by attracting shore birds. If standing water can infiltrate or be drained off the area in three days or less, dead leveling may be an option. If dead leveling is not used, the recommended slope is .025/100 feet. If standing water is a problem at the end of the irrigation run, a tailwater return system is recommended to reduce tree loss from waterlogging. As with most trees or crops, eucalyptus trees perform best under optimum soil and water conditions with deep, well-drained soil.

Timing of plantation establishment is important for a complete drainage water reuse system. If fresh water or water less then EC 3 dS/ m is available, then trees can be planted at the same time as halophytes.

Before planting trees, soils should be ripped or chiseled if the water table is not near the surface. Disk the area to control weeds and prepare soil for planting. Trees are planted in the bottom of furrows or on the leveled land. Planting the trees in the bottom of the furrows reduces salt load around the tree base as the sale accumulates on the top of the furrows. Planting the trees on the leveled land provides for the efficient salt leaching. Both methods can provide for the uniform distribution of water. Tree spacing within the row should be a minimum of eight feet. Tree row spacing will be determined by the width of equipment that will be used in the planting area. Allow two feet on each side of equipment (disk, mowers, spray rigs, etc.). For example, a 10-foot wide disk would require a row spacing of 14 feet. A wider spacing of 5 x 3 m (15 x 10 feet) is preferable. Trees can be planted using a mechanical tree planter. The ripper shank on the planter breaks up the soil and provides better root development for the new tree. If a tree planter is not available, hand planting can be done in a ripped or chiseled furrow. Proper spacing of trees is an advantage of hand planting.

Background information

In countries such as Australia, Egypt, Israel, and other arid regions, salt-tolerant trees have been irrigated with saline water. In 1985 the California Department of Food and Agriculture, the USDA-Soil Conservation Service, and the International Tree Crops Institute decided to try this concept in California. Eucalyptus seed was imported from the Province of Lake Albacutya in Victoria, Australia. The California Department of Forestry and private nurseries propagated seedlings.

Seedlings were first planted in Fresno and Kings Counties, primarily on farmland areas with high saline conditions that could not produce a crop. Survival was low on soils with high sodium levels. Sodium Absorption Ratios (SAR) exceeding 50 were primarily in Kings County.

In 1986 seedlings were propagated from seeds imported from Central Australia, Alice Springs, and surrounding areas. Some of these seedlings were interplanted in areas where the Lake Albacutya ones had died. They survived and selected trees were planted in areas with high saline and sodium conditions to determine their tolerance. Many other varieties of trees were planted in the same conditions. These included Eucalyptus from many provinces in Australia, Cottonwoods, Hybrid Cottonwoods, Athel, Salt cedar, Mesquite, Acacia, and Casurina obesa, cunninghamiana, glauca, and equisetifolia. Some of the varieties were irrigated with saline water of 6 to 20 dS/m and others with fresh water.

Pistachio

Other trees were also tried, including hybrid Willows and several varieties of Eucalyptus camaldulensis, rudis, robusta, occidentalis, grandis, viminalis, and tereticornis. Seedlings from old, established trees in Fresno and Kings Counties were also tried.

When the IFDM (Agroforestry) project started in the WRCD area (spring 1985), eucalyptus seeds were imported from Australia, Israel or Egypt, and the quality of propagated trees was inconsistent. To improve the quality of eucalyptus trees for IFDM/Agroforestry sites in the San Joaquin Valley, a selective breeding program was initiated in 1987. The IFDM/Agroforestry project team has worked closely with the California Eucalyptus Improvement Association (EIA) in its effort to coordinate the selection and propagation of superior trees. Trees are selected for salt tolerance, rate of growth, vigor, and frost tolerance. This selection effort has been successful, and most eucalyptus trees planted on irrigated farms since 1990 have been propagated from plant tissues and seeds developed in California. Selected trees have been systematically evaluated each year since 1989, and 22 trees have been chosen for tissue culture propagation. Two orchards have also been planted in experimental designs that facilitate the evaluation of growth characteristics of selected trees. Seed orchards have been established at several farms in the San Joaquin Valley, and at the USDA-NRCS Plant Material Center in Lockeford, California.

The IFDM program is oriented toward higher diversification of salt-tolerant trees and crops planted for salt management. Casuarina trees have been planted since 1985, but their performance has not always been satisfactory. Casuarina glauca is not frost tolerant; it was damaged by frost in 1990, and did not recover. Casuarina cumminghamiana has been frost damaged on several farms, and its recovery rate was lower than that of eucalyptus trees. Several individual trees performed very well under extremely difficult conditions (frost, salt, and drought). Athel (Tamarix aphylla) trees are well established in the valley, being mainly used as windbreaks. They are salt-tolerant and recover well from frost damage. They may be beneficial on farms where salinity levels are above EC 20. Eucalyptus seeds collected in 1994 from highly saline seeps in Australia and nearby surrounding areas are now being tested alongside the best clones.

Eucalyptus has been the most common salt-tolerant tree used for the management of salt and drainage. Positive results have been obtained from the management of trees over a 12-year period. Trees initially propagated on various sites in the Valley from seeds imported from Australia did not have uniform characteristics, as the growth rate and salt and frost tolerance varied significantly. The selection of superior trees through the valuable guidance of the Eucalyptus Improvement Association started in 1987/88. The best trees (4543, 4544, 4573, and 4590) were selected and are now propagated as clones by a nursery in Southern California. The selection and testing process continues with additional eucalyptus varieties.

Since 1985, more than 700,000 trees have been planted for the management of salt on irrigated farmland in the San Joaquin Valley. Eucalyptus camaldulensis is mainly planted at this time because of its salt tolerance, high water requirements, and relatively easy care.

The difference between Tamarisk Athel and Tamarisk Salt Cedar

Tamarisk Athel is an upright tree reaching up to 60 feet tall, with a dense spreading crown and several heavy large limbs. It is a fast-growing, evergreen tree. Its diameter is about 2.5 feet. The propagation method is vegetative. It commonly occurs on salt flats, springs, and other saline habitats. It is drought resistant and is tolerant of alkaline and saline soils. It uses large volume of water; a large tree can absorb about 200 gallons of groundwater per day. It does not colonize sites by seed.

Tamarisk Salt Cedar is a shrub growing up to 20 feet tall. It is considered a weed that produces a large amount of seeds and spreads in a wide area. It commonly occurs on salt flats, springs, and other saline habitats. It is drought resistant and is tolerant of alkaline and saline soils. It uses a large volume of water.

Tamarisk (Athel)

Reporting Requirements

Kathleen Buchnoff
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It is important to summarize the data to clearly illustrate compliance with all applicable regulatory requirements. Arrange the data in tabular form so the required information is readily discernible. Certain technical information needs to be submitted with the monitoring report. Daily evapotranspiration values of the nearest weather station from which information is available and copies of the laboratory analyses are to be submitted as part of the report. Weather data can be found at DWR's California Irrigation Management Information System, CIMIS, at: www.cimis.water.ca.gov.

Any person operating a solar evaporator should submit annual groundwater monitoring data and information at the earliest possible time, according to a schedule established by the RWQCB. The regional board shall notify the operator of each solar evaporator of the applicable submission schedule.

A. Examples of Water Monitoring Plans

The following three sections are examples of water monitoring plans listing some of the possible constituents that may need to be monitored. The RWQCB will determine the constituents that you will need to be monitored on your farm.

1. Applied Water Monitoring[1]

A station shall be established for measurement and collection of representative samples to measure the subsurface agricultural drainage water applied to the solar evaporator. Applied water monitoring may include the following:

Constituents	Units Measurement	Monitoring Type of Monitoring	Frequency
Mean Daily Flow	gpd	Meter	Continuous
Specific Electrical Conductivity	µmhos/cm or dS/m	Grab	Weekly
Standard Minerals[2]	mg/L	Grab	Quarterly
Trace Elements			
Selenium	µg/L	Grab	Monthly
Boron	µg/L	Grab	Quarterly
Arsenic	µg/L	Grab	Quarterly
Chromium	mg/L	Grab	Quarterly
Molybdenum	µg/L	Grab	Quarterly
Vanadium	µg/L	Grab	Quarterly

[1] Analysis of certain constituents may require specialized field procedures (e.g. filtration and preservation) and are recommended to be performed by a qualified technician.
[2] Standard minerals may include calcium, magnesium, sodium, potassium, alkalinity and sulfate.
µg/L = micrograms per liter
mg/l = milligrams per liter
µmhos/cm = micromhos per centimeter

2. Groundwater Monitoring[1]

Shallow groundwater should be monitored for all indicator parameters and constituents of concern. Samples should be collected from the installed wells and analyzed for the following:

Constituents	Units Measurement	Type of Monitoring	Monitoring Frequency
Depth	feet (tenths)	Measured	Quarterly
Specific Electrical Conductivity	µmhos/cm or dS/m @ 25C	Grab	Quarterly
Standard Minerals[2]	mg/L	Grab	Quarterly
Trace Elements			
Selenium	µg/L	Grab	Quarterly
Boron	µg/L	Grab	Quarterly
Arsenic	µg/L	Grab	Quarterly
Chromium	µg/L	Grab	Quarterly
Molybdenum	µg/L	Grab	Quarterly
Vanadium	µg/L	Grab	Quarterly

[1] Analysis of certain constituents may require specialized field procedures (e.g. filtration and preservation) and are recommended to be performed by a qualified technician.

[2] Standard minerals may include calcium, magnesium, sodium, potassium, alkalinity and sulfate.

3. Solar Evaporator Subsurface Drainage System (Tile Drain) Monitoring

If the solar evaporator is equiped with a subsurface drainage system, the drain should be monitored for the following:

Constituent	Units	Type of Measurement	Monitoring Frequency
Mean Daily Flow	gpd	Meter	Continuous
Specific Electrical Conductivity	µmhos/cm or dS/m @ 25C	Grab	Quarterly

B. Biological Monitoring

If standing water or other factors known to result in potential impacts to breeding and/or feeding birds are anticipated or have been demonstrated at a given IFDM site, the RWQCB, CDFG, and/or USFWS may determine that avian monitoring is required. Adequate avian monitoring at sites typically consists of the following:

1. Timing

Biological surveys should be conducted weekly during the predicted avian breeding season, which is approximately from February 1 through August 31. During the non-breeding season, from September 1 through January 31, surveys will be conducted monthly. Monitoring should be conducted in a way that does not keep birds actively incubating eggs off of the nest during the heat of the day, since this can result in clutch failure. All wildlife monitoring will be conducted by, or under the direct supervision of, a qualified wildlife biologist with, or able to obtain, permits, from the USFWS and the CDFG to collect the eggs.

Measuring Conductivity

2. Survey Components

Biological surveys will consist of:

1. Bird usage in the drainage management area, which includes the solar evaporator, halophyte plots, agroforestry plot or interceptor trees, sumps (including tail water), salttolerant grasses and adjacent crops will be documented by a qualified wildlife biologist. Data collected will at least include, but not be limited to, bird species present, approximate numbers of each bird species present, and any mating behaviors.
2. During the nesting season (approximately February 1 through August 31), a thorough search for nests and nesting activities should be conducted by a qualified wildlife biologist in and around the solar evaporator, halophyte plots, interceptor trees, sumps, and salt-tolerant grasses. Nests will be flagged, and nest fate monitoring will include counting nests, eggs and young. If shorebird nesting occurs on-site, one recurvirostrid (avian family which includes the Blacknecked Stilt and the American Avocet) egg will be randomly collected from each detected nest, with no more than a total of five random eggs from five separate nests being collected from a given IFDM site during a given nesting season, unless directed to do otherwise by USFWS and CDFG. The collected egg contents will be chemically analyzed for moisture content, total recoverable selenium, and, if necessary, the concentration of other trace elements by a USFWS-approved laboratory. The egg contents also will be assessed for embryonic deformities by a USFWS-approved laboratory. Eggs will be collected according to USFWS egg collection protocol.
3. Presence of any ponded water in or around the solar evaporator, halophyte plots, interceptor trees, salt-tolerant grasses and/or adjacent crops will be documented. An estimate of percent coverage and approximate depth of the ponded water will be noted.
4. Presence of any aquatic invertebrate species in or around the solar evaporator, halophyte plots, agroforestry plot, salt-tolerant grasses and/or adjacent crops should be documented. The type of invertebrates present should be identified to the family level, and abundance (dense, scattered, few) in each location should be noted. Presence of live algal mats in any of these designated areas should also be reported.
5. The presence or evidence of other wildlife species in or around the solar evaporator, halophyte plots, interceptor trees, salt tolerant grasses and/or adjacent crops should be documented.

3. Reporting Requirements

The results of each survey component will be submitted to the Central Valley Regional Water Quality Control Board. Results will be submitted within a week of the survey date. The weekly reports will not include results of egg analyses, since obtaining complete results usually requires several months. Survey results should be summarized in four quarterly reports. The quarterly reports should be submitted to the Board as follows:

Reporting Period	Due Date
January-March	1 May
April-June	1 August
July-September	1 November
October-December	1 February

The USFWS Sacramento Office Contaminants Division and CDFG Southern Sierra Region Office in Fresno should also receive copies of all monitoring reports.

C. Soil Monitoring

Soil monitoring is not required, but is recommended because it enables the tracking of the progress of the IFDM system (evaluate whether soil conditions are improving or declining) and provides information for fertilizer and nutrient applications. Generally, soil testing is performed once per year to measure EC, pH, and required anions and cations. Things to consider before sampling include:

- Field area (acres/sample)
- Sampling procedure
- Sampling depth

• Timing of sampling
• Sampling tools
• Sample handling
• Information forms
• Labs

There are numerous references for soil monitoring.

D. Salinity Monitoring

EM-38 surveys are not required, but may be helpful to evaluate salinity conditions in soil over time. See Figures 1 and 2.

Figure 1. EM-38 survey equipment

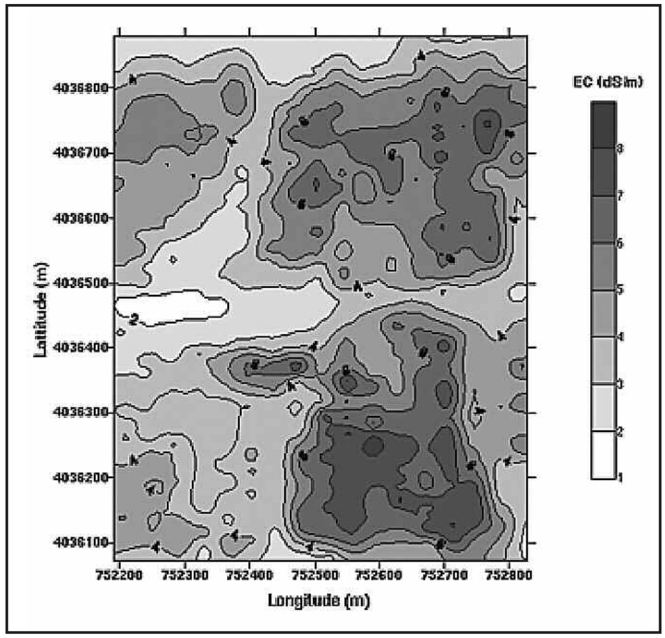

Figure 2. Salinity map created from EM-38 survey data. Values represented in this map are ECe (dS/m).

California Environmental Protection Agency

State Water Resources Control Board Water Quality Website

The California Environmental Protection Agency SWRCB Water Quality website www.swrcb.ca.gov/swamp/qamp.html outlines the sections and appendices of a Surface Water Ambient Monitoring Program (SWAMP) QAPP. The following table of contents is from the website:

Table of Contents

A helpful reference for QAPP development and preparation is DWR's "Guidelines for preparing a QAPP."

California Regional Water Quality Control Board

Central Valley Region

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Secretary for Environmental Protection

Gray Davis
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Mr. Gerald Stoltenberg
Westside Resource Conservation District
P.O. Box 205
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18 April 2002

DRAINAGE WATER BLENDING, WESTSIDE RESOURCE CONSERVATION DISTRICT, FRESNO COUNTY

Thank you for your letter of 18 March 2002, which asks for clarification on the regulatory requirements for the blending of drainage water used for the irrigation of salt tolerant crops.

Drainage water is a waste that can create nuisance conditions and/or affect the beneficial uses of waters of the state. The Regional Water Quality Control Board, Central Valley Region, (Regional Board) regulates discharges of wastewater that can affect waters of the state, including waste used for irrigation by agriculture. Examples include: packing house wastewater, food processing wastewater, biosolids, municipal wastewater reclamation, etc. While the Regional Board has the authority to regulate this waste using Waste Discharge Requirements (WDRs), drainage water is generally reused for irrigation without formal regulatory controls. In fact, the beneficial reuse of the drainage water can often result in water quality benefits by reducing the discharge of pollutants to surface waters.

The Regional Board generally considers drainage water applied on-farm a Non Point Source (NPS) of pollutants. However, compliance with the Clean Water Act, the Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code), and the Water Quality Control Plan for the Tulare Lake Basin, Second Edition, 1995 (Basin Plan) is not a voluntary choice. It is the Regional Board's responsibility to ensure compliance with these laws and regulations. The NPS strategy calls for three tiers of regulatory control. Tier 1: Self-Determined Implementation of Management Practices; Tier 2: Regulatory Based Encouragement of Management Practices; and Tier 3: Effluent Limitations and Enforcement Actions. Under Tier 1, the Westside Resource Conservation District could develop and implement workable solutions to NPS pollution control, which affords the opportunity to solve problems before more formal regulatory controls are taken. Potential problems can often be addressed through modifications in management measures that make formal regulatory control unnecessary. However, the reuse of drainage water must comply with the Basin Plan and State Water Resources Control Board Resolution No. 68-16, the State's "antidegradation" policy. The on-farm reuse of drainage water, if done properly and for beneficial use, should pose minimal threat to waters of the state. It may be possible to regulate the blending of drainage water for the irrigation of salt tolerant crops under the first tier if a demonstration can be made that the blended water is beneficially used for agricultural production. Examples of agricultural production would include the sale of a marketable crop or a crop grown for grazing. If the reuse of drainage water causes a nuisance, threatens to impair the beneficial uses of ground or surface waters, or is not beneficially used, then additional control and possibly enforcement actions may be needed.

The Regional Board considers the blending of drainage water to extend the water supply for agricultural production, a reasonable use of water. The blending of high quality water with poorer quality drainage water for its reuse on crops is generally accepted and encouraged. However, any operation that adds unusable drainage water to usable water and results in an unusable blend would probably be considered an unreasonable use of water.

In some cases, other regulations may apply. For example, the waste may be hazardous and subject to hazardous waste regulations contained in Title 22, California Code of Regulations, hazardous waste restrictions in the Basin Plan, and possibly the Resource Conservation and Recovery Act.

The Regional Board believes that a mechanism needs to be developed to ensure drainage water is used for agronomic benefit, protects water quality, and prevents nuisance conditions so that the discharge is not disposed of improperly. The challenge is to identify the potential problems that may develop with any reuse project and to develop practices that address the situation. Recently, you were awarded a Clean Water Act section 319(h) grant to develop an education and outreach program concerning Integrated On-Farm Drainage Management. The handbooks developed from that grant are required to outline the environmental and regulatory requirements, which should clarify what is necessary. The 319(h) grant should be used to identify management measures to achieve compliance with all applicable regulations.

If you have further questions please email or telephone Anthony Toto at totoa@rb5f.swrcb.ca.gov or (559) 445-6278.

LONNIE M. WASS
Supervising Engineer
RCE No. 38917

cc: Dr. Steve Schwarzbach, U.S. Fish and Wildlife Service, Sacramento
Ms. Frances McChesney, Office of Chief Counsel, State Water Resources Control Board, Sacramento
Mr. Walt Shannon, Division of Water Quality, State Water Resources Control Board, Sacramento
Mr. Dennis Westcot, Regional Water Quality Control Board, Sacramento
Mr. Bill Loudermilk, Department of Fish and Game, Fresno
Dr. Andy Gordus, Department of Fish and Game, Fresno
Ms. Paula Landis, Department of Water Resources, Fresno
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Calculating Case-Specific Costs of Integrated On-Farm Drainage Management

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The estimated costs of installing and operating an IFDM system presented in this report include several items that might not be required by all farmers. Some farmers might already have installed a subsurface drainage system and they might be implementing IFDM as a method of disposing the drainage water they collect in that system. Some farmers might choose not to hire a manager for the IFDM system or to assign management responsibilities to a current employee. Farmers also might choose to minimize their costs of producing halophytes and low-value, salt-tolerant crops and forages. Any of these decisions regarding installation and operation will reduce the farm-level cost of integrated on-farm drainage management.

In this Appendix, we describe how farmers and their advisors can estimate farm-specific costs of implementing IFDM. Information pertaining to individual farmers can be entered in Table A1. That information is used to generate Tables A2 through A4. The information required from farmers in Table A1 includes:

1. The estimated rental rate or opportunity cost of land,
2. The annual cost of taxes and assessments on land,
3. The production costs for low value salt-tolerant crops and forages,
4. The production costs for halophytes,
5. The estimated life of the drainage system and solar evaporator,
6. The interest rate to use when amortizing installation costs,
7. The initial cost of the subsurface drainage system,
8. The annual cost of operating and maintaining the drainage system,
9. The initial cost of the solar evaporator,
10. The annual cost of operating and maintaining the solar evaporator,
11. The annual cost of an IFDM system manager,
12. The area served by the subsurface drainage system,
13. The proportion of area used for the solar evaporator,
14. The proportion of area used for low value salt-tolerant crops and forages, and
15. The proportion of area used for halophytes.

The farm-specific values for these 15 parameters are used to calculate the annual cost of owning and operating the subsurface drainage system and the solar evaporator, and the annual costs of producing halophytes and salt-tolerant crops and forages (Table A2). The information in Table A2 is used to describe the estimated costs of IFDM by category in Tables A3 and A4. The costs in Table A3 pertain to the areas used for each activity. The estimated cost of the subsurface drainage system pertains to the size of area drained, while the estimated cost of the solar evaporator pertains to the number of acres required for the evaporator. The estimated costs of the subsurface drainage system and solar evaporator per acre of marketable crops appear in Table A4. Reducing the proportions of land required for the solar evaporator and production of halophytes and salt-tolerant crops and forages will reduce the estimated cost of IFDM per acre of marketable crops.

Sensitivity Analysis

The parameter values appearing in Table A1 and the results in Tables A2 through A4 pertain to the example presented in the text of this report. That example includes the following parameter values:

1. Estimated rental rate or opportunity cost of land: .... $150 per acre
2. Annual cost of taxes and assessments on land: .... $25 per acre
3. Production costs for salt-tolerant crops and forages: .... $339 per acre
4. Production costs for halophytes: .... $25 per acre
5. Life of the drainage system and solar evaporator: .... 10 years
6. Interest rate to use when amortizing installation costs: .... 6.25 percent
7. Initial cost of the subsurface drainage system: .... $400 per acre
8. Operating and maintaining the drainage system: .... $5 per acre
9. Initial cost of the solar evaporator: .... $1,000 per acre
10. Operating and maintaining the solar evaporator: .... $120 per acre
11. Annual cost of an IFDM system manager: .... $ 35,000 per year
12. Area served by the subsurface drainage system: .... 600 acres
13. Proportion of area used for the solar evaporator: .... 1 percent
14. Proportion of area for salt-tolerant crops and forages: .... 10 percent
15. Proportion of area for halophytes: .... 1 percent

This section examines the impact of selected changes in these parameter values on the farm-level cost of IFDM.

Farmers who can use land with zero opportunity cost for locating the solar evaporator and producing halophytes and salt-tolerant crops and forages can reduce the average cost of IFDM by about $20 per acre if all other parameter values remain the same as those appearing in Table A1. The cash and non-cash operating costs remain the same, while the non-cash overhead costs decline by about $20 per acre when land with zero opportunity cost is used for those activities (Table A5). Farmers who choose not to hire a manager for the IFDM system can reduce the cost by $35,000 per year or $66 per acre of land in marketable crops (Table A5). Farmers choosing to avoid any costs of production for halophytes and salt-tolerant crops and forages can reduce the average cost of IFDM by $38 per acre of land in marketable crops (Table A5). Farmers who already have installed a subsurface drainage system can implement IFDM for about $40 per acre less than farmers who must install a new drainage system (Table A5).

We examine also selected combinations of the cost-reduction measures described above. Farmers who choose not to hire a manager for the IFDM system and place the solar evaporator, halophytes, and salt-tolerant crops and forages on land with zero opportunity cost can reduce the average cost of IFDM from $176 per acre to $90 per acre (Table A5). Farmers who also have already installed a subsurface drainage system can implement IFDM for $50 per acre (Table A5). Farmers in this category who eliminate the costs of production for halophytes and low-alue, salt-tolerant crops and forages can implement IFDM for $12 per acre (Table A5).

Farmers and their advisors can use this framework to compute the average cost of installing and operating an IFDM system, given their current drainage situation and their choices of parameter values. The estimated average cost of implementing IFDM can be compared to the estimated net returns that farmers earn in crop production to determine if the investment is IFDM is sensible. For example, a farmer earning a net return above all costs of $62 per acre in cotton production can afford to implement IFDM if a drainage system already is installed, a manager is not hired, and the opportunity cost of land for the solar evaporator and production of halophytes and salt-tolerant crops and forages is zero. The average cost of IFDM is $50 per acre in that scenario (Table A5), leaving a net return of $12 per acre to the farmer. Similar comparisons can be made for any crops and parameter values selected by farmers considering an investment in IFDM.

See Appendix CD for Electronic Spreadsheet for Calculating Case-Specific Costs for Integrated On-Farm Drainage Management.

Table A1.

Parameter values used to calculate case-specific costs of an integrated on-farm drainage system

Estimated costs of land and the production of halophytes and salt-tolerant crops and forages	Annual Costs
	($/acre)
The estimated rental rate or opportunity cost of land	150.00
Annual cost of taxes and assessments	25.00
Production costs for salt-tolerant crops and forages	339.00
Production costs for halophytes	25.00

Financial Parameters			
	Estimated Life Life (in years)	Interest Rate	Amortization Factor
Drainage System	20	0.0625	0.089
Solar Evaporator	10	0.0625	0.137

Estimated costs of installing and maintaining the subsurface drainage system and evaporator	Initial Cost	Annual Costs
	($/acre)	($/acre)
The Subsurface Drainage System		
Estimated Installation Cost	400.00	
Amortized Installation Cost		35.58
Annual Operation and Maintenance		5.00
The Solar Evaporator		
Estimated Installation Cost	1,000.00	
Amortized Installation Cost		137.48
Annual Operation and Maintenance		120.00

The annual cost of an IFDM system manager	35,000.00	per year

Parameters describing the size of irrigated area and the proportions of total area used for the solar evaporator and production of salt-tolerant crops and forages, and halophytes		
The drainage system serves:	**600**	**acres**
Proportion of area in Solar Evaporator	1	percent
Salt-tolerant crops and forages	10	percent
Halophytes	1	percent
The size of the solar evaporator will be:	6	acres.
Area in salt-tolerant crops and forages	60	acres.
Area in halophytes	6	acres.
The net irrigated in production is:	**534**	**acres.**

Table A2.

The estimated costs of Installing, operating, and maintaining the solar evaporator and the estimated annual costs of land used for the evaporator, salt-tolerant crops, forages, and halophytes

Item	Initial Cost	Annual Costs
	($/acre)	($/acre)
The Subsurface Drainage System		
Estimated installation cost	400.00	
Amortized installation cost		35.58
Operation and Maintenance		5.00
Sum of Estimated Annual Costs for the Drainage System		40.58
The Solar Evaporator	($/acre)	($/acre)
Estimated installation cost	1,000.00	
Amortized installation cost		137.48
Operation and maintenance		120.00
Taxes and assessments		25.00
Rental or opportunity cost		150.00
Sum of Estimated Annual Costs for the Evaporator		432.48
Land Used for Salt-tolerant Crops and Forages		($/acre)
Taxes and assessments		25.00
Rental or opportunity cost		150.00
Annual production costs		339.00
Sum of Estimated Annual Costs for Salt-tolerant Crops		514.00
Land Used for Halophytes		($/acre)
Taxes and assessments		25.00
Rental or opportunity cost		150.00
Annual production costs		25.00
Sum of Estimated Annual Costs for Halophytes		200.00

Table A3.

The estimated costs of an IFDM system, by category, per acre of land used for each activity

Cost Category	Subsurface Drainage System	Solar Evaporator	Salt-tolerant Crops and Forages	Halophytes	System Manager
	($/acre)	($/acre)	($/acre)	($/acre)	($/acre)
Operating Costs	5.00	120.00	339.00	25.00	58.33
Non-Cash Operating Costs		25.00	25.00	25.00	
Non-Cash Overhead	35.58	287.48	150.00	150.00	
Total Costs	40.58	432.48	514.00	200.00	58.33

Table A4.

Cash and non-cash components of the estimated average annual cost of an IFDM system, per acre of land in marketable crops

Cost Category	Subsurface Drainage System	Solar Evaporator	Salt-tolerant Crops and Forages	Halophytes	System Manager	Total Costs
	($/acre)	($/acre)	($/acre)	($/acre)	($/acre)	($/acre)
Operating Costs	5.62	1.35	38.09	0.28	65.54	110.88
Non-Cash Operating Costs		0.28	2.81	0.28		3.37
Non-Cash Overhead	39.98	3.23	16.85	1.69		61.75
Total Costs	45.60	4.86	57.75	2.25	65.54	176.00

Note: These costs pertain to an IFDM system in which:

10 percent of the irrigated land is used to produce salt-tolerant crops and forages,
1 percent of the irrigated land is used to produce halophytes, and the size of the solar evaporator is
1 percent of the size of the irrigated area.

Table A5.

Sensitivity Analysis of the Costs of an Integrated On-Farm Drainage System

Scenario	Operating Costs	Non-Cash Operating Costs	Non-Cash Overhead Costs	Total Cost
		(Dollars per Acre)		
Original Scenario	111	3	62	176
Eliminate Individual Cost Items:				
Opportunity Cost of Land	111	3	42	156
Salary of a Manager	45	3	62	110
Costs of Production for Halophytes and Salt-Tolerant Crops and Forages	73	3	62	138
Drainage System Installation	111	3	22	136
Eliminate Combinations of Items:				
Opportunity Cost of Land and Salary of a Manager	45	3	42	90
Opportunity Cost of Land, Salary of a Manager, and Drainage System Installation	45	3	2	50
Opportunity Cost of Land, Salary of a Manager, Drainage System Installation, and the Costs of Production	7	3	2	12

Funding Sources

The three main funding sources to plan, design and implement an IFDM system are private financing, bank loans and grants. Grant programs may be from a public source (federal, state, regional and/or local), or from a private source. If the public grant source is used, it is important to remember that any financial records become public documents and are open for public review, and automatically require the implementation of CEQA and/or NEPA.

Current public grant programs may include:

- A state revolving fund available to growers in Westlands Water District for capital improvements to implement source reduction (subsurface drainage and irrigation equipment).
- The Federal USDA-NRCS EQIP grant program with funds available to growers for installing subsurface drains.

There are many funding resources available for possible grants and/or loan programs. Contact the local office of the following agencies or look on the Web for more information:

Federal

U.S. Department of Agriculture – Natural Resources Conservation Service
U.S. Department of Agriculture – Agricultural Research Service
U.S. Department of the Interior – Bureau of Reclamation
U.S. Fish and Wildlife Service
U.S. Environmental Protection Agency

State

Bay-Delta Authority (formerly CALFED Bay- Delta Program)
California Department of Water Resources
State Water Resources Control Board
Central Valley Regional Water Quality Control Board
California Department of Fish and Game
California Department of Food and Agriculture
University of California Cooperative Extension Service
California State University, Fresno – Center for Irrigation Technology

Regional/ Local

Resource Conservation districts
Water and Irrigation districts

Laws and Regulations

Gerald Hatler,
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Wayne Verrill, *Environmental Science, State Water Resources Control Board*
Mike Tietze, *Hydrogeology, MFG, Inc*

I. Introduction

An Integrated On-Farm Drainage Management system strives to provide an economically feasible and environmentally sound program for managing salts on irrigated farmland. Farmers who wish to develop an IFDM system must be aware of the myriad rules and regulations that govern water quality, wildlife protections and hazardous material.

Although the list of questions and considerations may seem daunting and overwhelming, there are technical and regulatory experts who can consult and work with growers to achieve a successful IFDM system. The key to this success is to develop a cooperative working relationship with the regulatory agencies and a willingness to maintain open dialogue and communications throughout the regulatory review and necessary environmental permitting process.

The assistance of a qualified biologist and/or planner is essential to navigating the environmental permit process. Consideration of the following questions and being prepared to provide a thorough and accurate description of all project activities should make the environmental compliance process easier and assist in successfully navigating any regulatory hurdles.

Please note, this chapter is merely a guideline to the complex process of environmental law and permitting. A more detailed account of the laws and regulations will appear in the technical manual for developing an IFDM system.

II. Questions That Should be Answered Before Proceeding with a Project

The following questions are intended to highlight features of the project that are often concerns for regulatory agencies.

- Has an Initial Study (IS) or Environmental Assessment (EA) been completed or is one being done by a local or state permitting agency in accordance with the California Environmental Quality Act (CEQA) or the National Environmental Policy Act (NEPA)?
- Will the project require certification, authorization or issuance of a permit by any local, state or federal agency?
- Have all adjacent landowners been contacted and notified before conducting any activity?
- Will the project require the issuance of a variance or conditional use permit by a city or county?
- Is the project currently operating under an existing use permit issued by a local agency?
- What types of vegetation are currently present at the project site, including trees, brush, grass, etc.?
- What types of wildlife or fish may use the project site or adjoining areas for habitat (food source, nesting, migration, water, etc.)?
- Has the California Department of Fish and Game (CDFG) or the U.S. Fish and Wildlife Service (USFWS) been consulted relative to the existence of, or impacts to, threatened or endangered species on or near the project site?
- Will the project result in changes to scenic views from existing residential areas, public lands, and public roads or present a visual distraction?
- Will the project impact existing recreational opportunities?
- Will the project result in changes or effects upon historical, or archeological and cultural resources?
- Will the project result in changes or effects upon geological or paleontological resources?
- Will the project include excavation?
- Will the project change existing features of any hills or result in substantial alteration of ground contours?
- Will the project occur on filled land or on a slope of 10 percent or more?
- Will the project discharge silt or other material into a designated body of water for California or the U.S.?

- Will the project involve the application, use, or disposal of hazardous material?
- Will activities or the completed project result in significant amounts of noise or vibration levels?
- Will activities or the completed project result in significant amounts of dust, ash, smoke, fumes or odors?
- Will the project involve the burning of brush, grass, trees or materials?
- Will the project substantially increase fossil fuel or energy resource consumption?
- Have any other similar projects been planned or completed in the same general area?
- Will the project have the potential to encourage, facilitate or allow additional new growth or development or impact local services?
- Will the project result in a change to the pattern, scale or character of the general project area?
- Will the project affect existing agricultural uses or result in the loss of existing agricultural lands?
- Will the project be funded by private or public funds?

III. Regulatory Requirements

Both state and federal agencies have the regulatory authority over projects like IFDM. The affected regulations that could impact an IFDM project include:

California Environmental Quality Act (CEQA):

CEQA was passed by the California Legislature in 1970. Generally, CEQA requires state and local agencies to identify the significant and potentially significant environmental impacts of their actions and to implement measures to avoid or mitigate for those impacts. If a significant effect is anticipated, an Environmental Impact Report (EIR) is written; otherwise; a Negative Declaration is prepared.

National Environmental Policy Act (NEPA):

NEPA requires incorporating environmental considerations into the planning process for all federal projects and for projects requiring federal funding or permits. If a significant effect is anticipated, an Environmental Impact Statement (EIS) is written; otherwise, a Finding of No Significant Impact (FONSI) is prepared.

Note: *Projects that are developed by state or federal agencies, and/or funded or permitted by state or federal agencies must address CEQA and NEPA. Projects that involve state participation must conform with CEQA, while projects with federal participation must conform to NEPA guidelines. Projects with both state and federal interests are subject to environmental analyses under both acts.*

Federal Clean Water Act:

The Federal Clean Water Act established the basic structure for regulating discharges of pollutants into the waters of the United States. The act sets water quality standards for all toxic and nontoxic contaminants in surface waters, implements wetland protection programs, and charges the states to adopt standards and to establish treatments and controls to protect water quality within its borders.

Section 404, Clean Water Act:

Section 404 of the Clean Water Act regulates the location of a structure, excavation and discharge into "waters of the United States," which can include wetlands, perennial or ephemeral streams and lakes. The U.S. Environmental Protection Agency and U.S. Army Corps of Engineers have primary jurisdiction and issue permits under Section 404.

Section 402, Clean Water Act:

Section 402 requires that all point sources discharging pollutants into waters of the United States obtain a National Pollutant Discharge Elimination System Program (NPDES) permit. Point source pollutants are defined as those that come from a concentrated point of origin such as a pipe, factory, feedlot or those coming from a readily determined source, as opposed to non-point pollutants, which come from diffuse sources. The Regional Water Quality Control Board regulates the Section 402 permits.

Resource Conservation and Recovery Act (RCRA):

RCRA is the federal statute governing management and disposal of waste. In the case of salt residue from an IFDM system, the material is not a listed hazardous waste. However, it could be a characteristic hazardous waste if the leachable selenium concentration in the solid residue (or the dissolved selenium in disposed liquid) exceeds the allowable level of 1.0 milligrams per liter (mg/L) using the Toxicity Characteristic Leaching Procedure (TCLP).

Note: *The California State Water Resources Control Board is currently developing a resolution under SB 1372 (Title 27 Draft Regulations) that would simplify some of the regulatory requirements for management of salt residue from an IFDM system. The proposed resolution would allow for on-site storage of salt residue for periods of up to one year under certain conditions. It is not clear whether the resolution would exempt the salt residue from RCRA storage and management requirements for this duration if selenium levels in the residue exceed hazardous levels.*

Hazardous Waste Control Law (HWCL):

HWCL is the California statute governing management and disposal of hazardous waste. California requirements are generally similar to requirements under RCRA, except that additional requirements may apply to salt waste from an IFDM system.

Land Disposal Restrictions (LDR):

Certain hazardous wastes are banned from land disposal unless they are treated to meet certain standards. This treatment is generally performed by the disposal facility. Selenium waste waters must be treated to a standard of 1.0 mg/L prior to disposal and non-wastewater wastes must be treated to a leachable concentration of 5.7 mg/L as determined by TCLP.

Toxic Pits Cleanup Act (TPCA):

TPCA was enacted in 1984 to regulate the cleanup of pits historically used for the disposal of liquid hazardous waste in California. Because drainage discharged to solar evaporators sometimes contains naturally occurring selenium in excess of hazardous waste levels, certain requirements of TPCA were automatically triggered. This issue has been addressed by SB 1372 (Title 27 Draft Regulations), which recognizes that TPCA was not intended to address the unique circumstances and conditions pertinent to solar evaporators, and therefore exempts IFDM systems from this regulation.

Porter-Cologne Water Quality Control Act:

The Porter-Cologne Water Quality Control Act of California requires that nine Regional Water Quality Control Boards (RWQCBs) be created to regulate water quality through the establishment and enforcement of Basin Plans that define beneficial use quality objectives for water resources in their respective areas. Any waste disposal activities or releases that impact or threaten to impact the quality of "waters of the state" (either surface water or groundwater) may be regulated. Waste disposal is regulated by issuing Waste Discharge Requirements (WDRs) that specify measures that must be taken and monitoring requirements that must be followed to assure that water quality is not impacted.

Note: *Under SB 1372 (Title 27 Draft Regulations), the State Water Resources Control Board (SWRCB) will adopt a resolution that waives WDRs for IFDM systems. The resolution will require that operators of IFDM systems follow a series of simplified requirements that are essentially generic WDRs for these operations and are intended, among other things, to prevent potential impacts to water quality. If these requirements are not followed and a discharge from an IFDM system impacts or threatens groundwater or surface water quality, a RWQCB could order that the release be investigated or could issue a cease and desist order requiring cleanup.*

CCR Title 27 Landfill Regulations:

The disposal of non-hazardous, non-inert waste is regulated under Title 27 of the California Code of Regulations. Under these regulations, non-hazardous waste that has the potential to degrade water quality is defined as "Designated Waste," and must be disposed of in properly designed and classified surface impoundments with liners that are licensed to accept such waste.

RCRA Subtitle D Landfill Requirements:

Design, monitoring and closure requirements for hazardous waste landfills are outlined in Subtitle D of RCRA and in Titles 22 and 23 of the California Code of Regulations. The requirements now being considered in the resolution drafted by the SWRCB pursuant to SB 1732 are not consistent with these requirements. It is not clear whether salt residue containing selenium above TCLP, STLC and/or TTLC concentrations will be permitted to be disposed in place without these requirements being triggered.

Section 401, Clean Water Act, Water Quality Certification:

Under CWA Section 401, a landowner that applies for a federal permit or license for an activity that could result in a discharge to “waters of the United States” must also obtain a State Water Quality Certification that the discharge meets state water quality objectives. Most Water Quality Certifications are associated with CWA Section 404 permits.

Basin Plans or Water Quality Control Plans:

The development of basin plans was required by the state Porter-Cologne Water Quality Act (sections 13240-13247) and the federal Clean Water Act (section 303). The basin plans consist of designated beneficial uses to be protected, water quality objectives for groundwater and surface water and an implementation program for meeting the objectives. Basin plans are administered by the RWQCBs and are used by other agencies in permitting and resource management activities.

Federal Endangered Species Act (FESA):

This act affords regulatory protection to plant and animal species federally listed as endangered, threatened, or proposed for listing. The act includes a provision (Section 9) that prohibits parties from the import, export, possession, transport, sale, or the unauthorized “take” of any listed species, which includes harassing, harming (which includes significantly modifying or degrading habitat), pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting wildlife or any attempt to engage in such conduct.

California Endangered Species Act (CESA):

This act establishes a state policy to conserve, protect, restore, and enhance threatened or endangered species and their habitats. CESA mandates that a state agency cannot approve a project that potentially jeopardizes the continued existence of a listed species when reasonable and prudent alternatives exist. A state lead agency must consult with CDFG during the CEQA process. CDFG will issue comments addressing their concerns and will offer reasonable and prudent alternatives for a project.

Stream Bed Alteration Agreement – Fish and Game Code, section 1600:

CDFG requires notification from agencies and/or individuals prior to taking any action that would divert, obstruct, or change the material, flow, bed, channel, or bank of any river, stream, lake or any other waterway that may provide aquatic habitat. CDFG will propose reasonable project changes if the project has the potential to negatively affect resources. CDFG will seek to protect fish and wildlife resources and may stipulate conditions to protect these resources.

Fully Protected Animals:

The state attempted to identify and provide protection to those animals that were rare or faced possible extinction prior to CESA under various legislative bills. This resulted in a list of 37 mammals, birds, reptiles and amphibians that were given Fully Protected status, (see Appendix). Under the more recent endangered species laws and regulations, most Fully Protected species also have been listed as threatened or endangered species. However, Fully Protected species may not be taken or possessed at any time and no licenses or permits (including a 2081) may be issued for their take except in rare circumstances.

Migratory Bird Treaty Act:

This act is the result of a series of conventions with Canada, Japan, Mexico and Russia establishing a federal statute that prohibits the pursuit, hunt, take, capture, kill, attempt to take, capture or kill, possess, offer for sale, sell, offer to purchase, purchase, deliver for shipment, ship, cause to be shipped, deliver for transportation, transport, cause to be transported, carry, or cause to be carried by any means whatever, receive for shipment, transportation or carriage or export at any time or in any manner, any migratory bird, unless permitted by regulations. This includes feathers, nests, eggs, other parts, or products of a migratory bird. Most birds are protected under this act.

Bald Eagle Protection Act:

This law provides for the protection of the bald eagle (the national emblem) and was later amended to include the golden eagle by prohibiting the take, possession, sale, purchase, barter, offer to sell or purchase or barter, transport, export or import at any time or in any manner a bald or golden eagle, alive or dead; or any part, nest or egg of these eagles. By definition, take includes: pursuing, shooting, poisoning, wounding, killing, capturing, trapping, collecting, molesting, or disturbing.

California Reclamation Board:

The California Reclamation Board was established to control flooding along the Sacramento and San Joaquin rivers and their tributaries, to assist in establishing and maintaining flood control works and the integrity of the existing flood control systems, and is required to enforce standards that will best protect the public from floods. The Board's jurisdiction extends over the entire Central Valley and includes the Tulare and Buena Vista basins. An encroachment permit application must be submitted to the Board for review if a project falls within the Board's jurisdictional area.

IV. Environmental Evaluation Resources

Many useful resources are available to make the environmental evaluation and permit process easier, but nothing can substitute for the assistance provided by qualified professionals. Below are just some of the resources available. Many are available online.

Note: *An attempt has been made to provide the parent website for resources rather than the actual link as websites continually change and direct links often expire within a short period of time. You may be required to navigate and search a website to find the listed resource.*

Biological Data

The Wildlife and Habitat Data and Analysis Branch of CDFG provides useful tools and resources to consultants and agency personnel to evaluate impacts to biological resources. Some of the information is available to the general public and some is provided through a subscription based service.

Species Lists

The following species lists are available from CDFG:

- *Complete List of Amphibians, Reptiles, Birds and Mammals in California*
- *State and Federally Listed Endangered and Threatened Animals of California*
- *Special Animals*
- *State and Federally Listed Endangered, Threatened, and Rare Plants of California*
- *Special Vascular Plants, Bryophytes, and Lichens List*

California Technology, Trade and Commerce Agency – California Permit Handbook

http://commerce.ca.gov

The California Technology, Trade and Commerce Agency provides an online guide (and print version) to the state's environmental permit process. The Handbook contains useful summaries, tips and contacts to help you understand the permit process.

CERES – CEQA Website

www.ceres.ca.gov

The California Environmental Resources Evaluation System (CERES), under the California Resources Agency, maintains a CEQA website that provides the CEQA guidelines, forms, and numerous CEQA resources.

Governor's Office of Planning and Research

www.opr.ca.gov

The State Clearinghouse, under the Governor's Office of Planning and Research, is the point of contact for the distribution of environmental documents prepared under CEQA. The State Clearinghouse Handbook provides information about CEQA and the environmental document review process.

California Department of Fish and Game

www.dfg.cal.gov

Reclamation Board

www.recbd.water.ca.gov

State Water Resources Control Board

www.swrcb.ca.gov

US Army Corps of Engineers, Regulatory Program

www.usace.army.mil/inet/functins/cw/cecwo/reg

US Fish and Wildlife Service, Permits

http://permits.fws.gov

V. Answers to the Most Common Questions Concerning the Solar Evaporator Regulations

Definition:

What is the regulatory definition of a solar evaporator?

Linked regulatory definitions have been established by the State Legislature for "solar evaporator, integrated on-farm drainage management system, and on-farm."

A solar evaporator is designed and operated to manage agricultural drainage water discharged from an integrated on-farm drainage management system. The integrated on-farm drainage management system (1) collects drainage water from irrigated fields and sequentially reuses that water to irrigate successive crops until the volume of residual agricultural water is substantially decreased and its salt content is significantly increased; (2) reduces the level of salt and selenium in the soil; (3) discharges the residual agricultural drainage water to an on-farm solar evaporator for evaporation and appropriate salt management; (4) eliminates discharge of agricultural drainage water outside the boundaries of the property that produces the agricultural drainage water managed by the system.

Finally, "on-farm" means within the boundaries of a geographically contiguous property, owned or under the control of a single owner or operator, that is used for the commercial production of agricultural commodities and that contains an IFDM system and a solar evaporator. These linked definitions constitute a permitable solar evaporator under the new regulations. For the complete text of the definitions, see the California Code of Regulations (CCR) §22910.

How can a solar evaporator be integrated into my existing farming operation?

An IFDM system, including a solar evaporator, can be established in the entirety or a portion of your contiguous property that is currently used or will be used for commercial agricultural production, depending on your need to manage saline shallow groundwater.

Application Process:

What is the procedure for applying for and obtaining a permit to construct and operate a solar evaporator?

At present, any person who intends to construct and operate a solar evaporator shall first file a Notice of Intent (NOI) with the Regional Water Quality Control Board (RWQCB). The NOI (see Appendix) consists of a one-page form, plus supporting documentation, including the design of the solar evaporator, calculation of the maximum rate of drainage discharge to the solar evaporator, baseline groundwater monitoring data, and a local water balance analysis (annual evapotranspiration, ET, and precipitation). The solar evaporator design must be certified by a registered professional who is a civil or agricultural engineer, or a geologist or engineering geologist.

The RWQCB shall, within 30 days of receiving the NOI, review the NOI and inspect the proposed location, and if the NOI is found to be in compliance with the regulations, issue a written Notice of Plan Compliance (NPC). If the NOI is found to not be in compliance, the RWQCB shall issue a written response to the applicant identifying the reasons for non-compliance. The applicant can then take steps to revise the NOI in order to bring it into compliance.

After receiving an NPC, an applicant may proceed with construction of the solar evaporator in conjunction with an IFDM system. Before operating the solar evaporator, the applicant must request the RWQCB to conduct a compliance inspection. The RWQCB will conduct the inspection within 30 days of receiving the request, and if the solar evaporator is in compliance with the NOI and NPC, will issue a Notice of Authority to Operate (NAO). If upon inspection, the solar evaporator is found to not be in compliance, the RWQCB will issue a written response identifying the reasons for non-compliance. The applicant can then take steps to modify the solar evaporator in order to bring it into compliance with the NOI and NPC.

For the actual text of the procedures, see the Health and Safety Code (HSC) §25209.13.

Please note that these regulations may be subject to change.

Who can submit an application?

The permitable applicant of a solar evaporator facility has been defined by the State Legislature as a single owner or operator of a geographically contiguous property that is used for the commercial production of agricultural commodities with an IFDM system.

When can an application be submitted?

An application can be submitted at any time, but an NAO cannot be issued on or after January 1, 2008.

Will an Environmental Impact Report be required?

A CEQA checklist and initial study need to be completed to determine any additional environmental regulations that might apply.

Solar Evaporator Design Requirements:

What are the requirements for choosing a site for a solar evaporator?

The solar evaporator may be located anywhere on your agricultural property within the boundary of and contiguous with your IFDM system. The solar evaporator should NOT be located on the low point of the farm, and should be placed above the 100-year floodplain, and where the criteria for groundwater protection may be met.

The criteria include a one-meter depth of soil with permeability of 1 x 10-6 cm/sec or less, and a distance of five-feet or more between the bottom surface of the solar evaporator and the highest anticipated level of underlying shallow groundwater. Sites not meeting these conditions may be engineered to achieve the same level of flood and groundwater quality protection.

What types of solar evaporator designs will be permitted?

Any solar evaporator design can be permitted if it meets the basic design requirements of the new regulations. In addition to flood and groundwater quality protection, the design must include no discharge of agricultural drainage outside of the solar evaporator; discharge to the solar evaporator must be by sprinklers or another adjustable mechanism that will prevent the occurrence of standing water; wind drift of sprinkler spray shall be prevented; and avian wildlife shall be adequately protected.

A water catchment basin may be constructed as part of the solar evaporator in order to contain standing water that might otherwise occur in the solar evaporator. The maximum size of the solar evaporator cannot exceed 2 percent of the total area of the complete IFDM system.

What is a water catchment basin?

A water catchment basin is an area within the boundaries of a solar evaporator designed to receive and hold any water that might otherwise become standing water within the solar evaporator under reasonably foreseeable operating conditions. The entire area of the water catchment basin needs to be permanently covered with netting or otherwise constructed to ensure protection of avian wildlife.

What is meant by "reasonably foreseeable operating conditions?"

"Reasonably foreseeable operating conditions" were stated by the State Legislature as defining the regulatory limits for the design of a solar evaporator, but were not quantified. The SWRCB has quantified these conditions as follows:

- the local 25-year, 24-hour maximum precipitation event,
- floods with a 100-year return period.

This means that the solar evaporator must be designed to not have standing water in the event of a 25-year, 24-hour precipitation amount, or that the water catchment basin must have sufficient volume to hold that amount of water accumulating in the solar evaporator. If a storm event occurs exceeding that amount, any associated occurrence of standing water within the solar evaporator will not be considered a violation of the regulations. In an analogous manner, inundation of the solar evaporator by a flood event exceeding the 100-year return period will also not be considered a violation of the regulations.

Is the use of a liner required?

Use of a liner is not required. Although, a liner may be used to meet the requirements for groundwater quality protection if existing soil conditions are unfavorable, and other engineered solutions are infeasible. In this case, the liner must meet the stated specifications, including a thickness of 40-millimeters.

If the groundwater quality protection requirement is met without use of a liner, an owner/operator may use a liner at his discretion, as a functional component of the solar evaporator design. In this latter case, the 40-millimeter thickness specification does not apply.

Is the installation of a subsurface drainage system required?

Subsurface drainage systems under or adjacent to a solar evaporator are not required. Subsurface drainage systems may be installed where it is deemed necessary to provide adequate insurance that groundwater quality will be protected.

Solar Evaporator Operation Requirements:

What are the operational requirements for solar evaporators?

The solar evaporator must be operated so that:

- There is **no standing water** within the evaporator, except for the water catchment basin. Application of drainage water with a timed sprinkler system should be used to set the application at rate that will not result in standing water.
- A nuisance condition such as wind-blown salt spray is not created.
- There is **no discharge of drainage water** outside the boundaries of the solar evaporator.
- Avian wildlife is adequately protected.

What steps are necessary to ensure the adequate protection of avian wildlife?

In addition to no standing water, the following Best Management Practices are required to ensure adequate protection of avian wildlife:

- Keep the solar evaporator free of all vegetation.
- Do not use grit-size gravel as a surface substrate in the solar evaporator.
- Prevent access to standing water in a water catchment basin with netting and do not allow the netting to sag into standing water in the catchment basin.
- Prevent the growth of insects in the solar evaporator, the growth and dispersal of insects from the water catchment basin, and use of the netting as a site for insect pupation.

What are the monitoring requirements?

Monitoring requirements will be established by the Regional Board at the time of the issuance of a Notice of Plan Compliance within 30 days of the submittal of a Notice of Intent to construct a solar evaporator. Groundwater and avian wildlife protection monitoring shall be required, as well as any information necessary to ensure compliance with the requirements of the regulations. Monitoring reports shall be submitted annually.

What options are available for the storage of salt accumulated in the solar evaporator?

Salt may continue to accumulate in an authorized solar evaporator as long as the accumulation does not interfere with the required operation of the evaporator. Salt may be harvested at any appropriate time and utilized or sold for beneficial of commercial purposes. Otherwise, salt can be temporarily stored in an enclosed storage unit inaccessible to wind, water and wildlife, and subject to annual inspection.

Are inspections separate from monitoring?

Yes. Monitoring and other recordkeeping is the responsibility of the operator.

Inspections are the responsibility of the Regional Board and shall be conducted at least once annually during the month of May. Inspection shall be made for observations indicating a threat to avian wildlife including:

- presence of vegetation within the perimeter of the solar evaporator;
- standing water and the growth of insects;
- presence of birds or nests with eggs within the perimeter of the solar evaporator;
- an avian die-off or disabling event associated with the solar evaporator.

Solar Evaporator Closure Requirements:

How long can I continue to operate a solar evaporator?

The Notice of Authority to Operate must be renewed every five years. Renewal can be achieved as long as the solar evaporator continues to meet the State and Regional Board requirements. As long as the Notice of Authority is renewed and is in effect, closure is not required.

If closure is necessary or desired, what requirements have to be met?

Three options are available for closure: (1) harvest of salt followed by clean closure; (2) closure in place; (3) removal of salt and disposal in an authorized waste facility. The operator will select the closure option, and submit a plan to the regional board for approval.

• **Clean closure:** The salt from the solar evaporator may be harvested and utilized following the guidelines under salt management. After the removal of the salt, the solar evaporator and surrounding area need to be restored to a condition that does not threaten wildlife, does not threaten to pollute water, and does not cause a nuisance condition.

• **Closure in place:** A cover can be constructed over the solar evaporator retaining salt inplace and making use of the existing foundation.

• **Waste Facility Disposal:** Salt may be removed and disposed permanently in an authorized waste facility. After salt removal, the solar evaporator site is clean closed as above.

For complete requirements, see CCR §22950.

Additional Details for Laws and Regulations

The material above in Laws and Regulations briefly outlines the various laws and regulations that may apply to development of an IFDM system. Additional details for each law are discussed here:

California Environmental Quality Act (CEQA): The California Public Resource Code §21000-21006 establishes the legislative intent and policy supporting the CEQA environmental disclosure and review process for projects conducted in the State of California. Public Resource Code §21065 defines a project as:

"an activity which may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment, and which is any of the following:

(a) An activity directly undertaken by any public agency.

(b) An activity undertaken by a person which is supported, in whole or in part, through contracts, grants, subsidies, loans, or other forms of assistance from one or more public agencies.

(c) An activity that involves the issuance to a person of a lease, permit, license, certificate, or other entitlement for use by one or more public agencies."

Any project that fits the above definition, whether undertaken by a private or public entity, is subject to the CEQA process. An overview of the CEQA process is illustrated in Figure 1. Early in the process, a lead agency is designated. Generally, the lead agency is the California government agency principally responsible for approving or carrying out a project. The lead agency is responsible for preparing all necessary environmental disclosure documentation, for assuring that the documentation is legally adequate, and for encouraging public participation. Other agencies, known as responsible agencies, also may be directly involved with the CEQA process. These agencies are legally responsible for some aspect of the project or resource in the project area and will provide input to the lead agency as the project is planned and CEQA documentation is prepared. It is common for public agencies with permitting authority over a project to serve as responsible agencies. Once a lead agency is designated, an IS is prepared to help determine whether the project could have any significant effect on the environment. If a significant effect is anticipated, an Environmental Impact Report (EIR) is written, otherwise a Negative Declaration is prepared.

CEQA documentation is prepared not only to fully inform decision makers about the details and any possible impacts of a project before deciding whether to proceed, but it's also prepared to fully inform the general public about a proposed project and any potential impacts. The public disclosure aspect of CEQA is stressed in the CEQA statute, and protocols that facilitate public disclosure and interaction are provided in the CEQA guidelines (http://www.ceres.ca.gov/).

Although the CEQA process is outlined and discussed in the guidelines, it is best to let someone with a strong CEQA background determine which level of environmental analysis is appropriate for the proposed project, and to then complete the necessary actions to ensure CEQA compliance.

National Environmental Policy Act (NEPA): NEPA requires incorporating environmental considerations into the planning process for all federal projects, and for projects requiring federal funding or permits.

The purposes of this Act are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality [CEQ]. Sec. 2 [42 USC § 4321], Federal Code.

Unlike CEQA, NEPA allows each federal agency to develop their own NEPA guidelines; however, the CEQA requires that each agency's NEPA policy integrate environmental impact analysis into project planning and environmental disclosure documents including:

EA's and Environmental Impact Statements (EIS). Like CEQA, public disclosure and interaction are mandated by NEPA.

Federal Clean Water Act: The act specifies that federal agencies identify reasonable alternatives to a proposed project along with the preferred alternative (the proposed project), as well as describing any anticipated impacts.

Typical activities that affect water quality may include but are not limited to:

- Discharge of process wastewater and commercial activities not discharged into a sewer (factory wastewater, cooling water, etc.)
- Confined animal facilities (e.g., dairies)
- Waste containments (landfills, waste ponds, etc.)
- Construction sites
- Boatyards
- Discharges of pumped groundwater and cleanup (underground tank cleanup, dewatering, spills)
- Material handling areas draining to storm drains
- Sewage treatment facilities
- Filling of wetlands
- Dredging, filling, and disposal of dredge wastes
- Waste to land

Various agencies have been granted regulatory authority over different aspects of the Clean Water Act. Sections of the Clean Water Act most relevant to Integrated Farm Drainage Management (IFDM) projects may include:

Section 404, Clean Water Act: Waters of the United States are divided into "wetlands" and "other waters of the United States." Wetlands are defined as *"areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions"* (33 Code of Federal Regulations [CFR] 328.3[b], 40 CFR 230.3). Jurisdictional wetlands must support positive indicators for hydrophytic vegetation, hydric soil, and wetland hydrology. Other waters of the United States are defined as those that lack positive indicators for one or more of the three wetland parameters identified above and include seasonal or perennial water bodies, including lakes, stream channels, drainages, ponds, and other surface water features, that exhibit an ordinary high-water mark (33 CFR 328.4).

Section 402, Clean Water Act: Common pollutants that are subject to NPDES permit limitations are biological waste, toxic chemicals, oil and grease, metals, and pesticides. NPDES permitting is administered by the Regional Water Quality Control Board (RWQB) under the authority of the State Water Resources Control Board (SWRCB).

Resource Conservation and Recovery Act (RCRA): In California, RCRA is enforced by local Certified Unified Program Agencies (CUPAs) and the Department of Toxic Substances Control (DTSC). When it was enacted in 1976, it introduced the concept of "cradle to grave" management of hazardous waste as well as use of the Uniform Hazardous Waste Manifest. Under RCRA, in order for a substance to be considered a hazardous waste, it must first be a waste (i.e., you are done using it and/or it is inherently "wastelike"). Secondly, the waste must either (1) be on a list of wastes that are automatically considered to be hazardous; or (2) display characteristics that make it a hazardous waste (i.e., toxicity, ignitability, reactivity or corrosivity).

If the waste is hazardous under RCRA, the generator must file a notification with EPA and obtain a hazardous waste generator identification number, comply with requirements for appropriate storage of the material prior to shipment, ship the material under a Uniform Hazardous Waste Manifest using a hauler licensed to transport hazardous waste, and dispose of the material at a specially licensed treatment or disposal site. Selenium and selenium compounds are considered Acutely Hazardous Wastes under RCRA. If the amount of Acutely Hazardous Waste generated exceeds 1 kilogram (kg) in any given month, then the generator is responsible to comply with additional reporting, training, storage and waste minimization requirements.

Finally, the generator is responsible for the waste even after it is deposited in a disposal facility. This means that the generator could ultimately be responsible to contribute funds to clean up of the disposal facility, if that were to be required in the future. Of note is the fact that if a hazardous waste is recyclable, it is subject to RCRA storage and handling requirements, but there is no long-term liability. If the salt residue were a commercial product and not a waste, it would not be subject to RCRA requirements.

Hazardous Waste Control Law (HWCL) is codified in the Health & Safety Code Division 20, Chapter 6.5 and implementing regulations found in California Code of Regulations, Title 22, Division 4.5. The requirements of the HWCL are enforced by the local CUPA and/or DTSC.

Hazardous Waste Control Law (HWCL): California defines characteristic hazardous wastes based on either (or both) the soluble or total concentration of a hazardous constituent.

For selenium, this is defined as a Soluble Threshold Limit Concentration (STLC) of 1.0 mg/ L as determined by the California Waste Extraction Test or a Total Threshold Limit Concentration of 100 mg/kg. Hazardous waste generated in California is subject to additional reporting requirements and a hazardous waste generator tax levied by the state Board of Equalization. Any treatment of hazardous waste at a site to change its characteristics or render it less toxic is subject to additional regulatory and permitting requirements.

Section 404, Clean Water Act: Certain ongoing, normal farming practices in wetlands are exempt and do not require a permit. This includes, among other things, maintenance (but not construction or alteration of) drainage ditches, construction and maintenance of irrigation ditches, and construction and maintenance of farm or stock ponds. In order to be exempt, the activities cannot be associated with converting an agricultural wetland into a non-wetland or bringing a wetland into agricultural production. Other requirements define and regulate "Prior Converted Cropland" and "Farmed Wetlands."

Federal Endangered Species Act (FESA): Actions that lead to take can result in civil or criminal penalties. Authorization for "take" must be received from the appropriate federal regulatory agency (USFWS, NOAA Fisheries, etc.), if compliance with standard avoidance measures are not feasible. Section 10 outlines the process by which entities may obtain a permit for the "incidental take" of a listed species.

Under Section 7 a federal lead agency must consult with relevant federal regulatory agencies to ensure that the actions of a project do not jeopardize the continued existence of listed species. If the project has the potential to affect listed species, a federal lead agency must prepare a Biological Assessment (BA) identifying the project effects and submit it to other federal agencies for review. The reviewing federal agencies would make a determination regarding effects and proposed mitigation measures and, after consultation, issues a Biological Opinion (BO) that may authorize "take" but could lead to changes in avoidance and mitigation measures and may require modification of the project design.

If the project affects species listed jointly under the federal and state Endangered Species Acts, DFG typically participates in Section 7 consultation to the greatest extent possible. The federal BO generally reflects both state and federal findings, and DFG is encouraged in the state Endangered Species Act to adopt, when possible, the USFWS biological opinion as its own formal written determination on whether jeopardy to endangered species exists. If, however, USFWS and DFG ultimately fail to agree, the agencies may issue independent biological opinions.

California Endangered Species Act (CESA): Section 2080 of the Fish and Game Code prohibits "take" of any species that the Fish and Game Commission determines to be an endangered species or threatened species. Take is defined in Section 86 of the Fish and Game Code as *"hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill."* CESA allows for take incidental to otherwise lawful development projects but emphasizes early consultation to avoid potential impacts to rare, endangered, and threatened species and to develop appropriate mitigation planning. Mitigation planning is intended to offset project caused losses of listed species populations and their essential habitats.

Sections 2081(b) and (c) of the California Endangered Species Act allow the Department to issue an incidental take permit for a State listed threatened and endangered species only if specific criteria are met. Title 14 California Code of Regulations (CCR), Sections 783.4(a) and (b) summarizes the criteria as: *"The authorized take is incidental to an otherwise lawful activity; The impacts of the authorized take are minimized and fully mitigated; The measures required to minimize and fully mitigate the impacts of the authorized take are roughly proportional in extent to the impact of the taking on the species, maintain the applicant's objectives to the greatest extent possible, and are capable of successful implementation; Adequate funding is provided to implement the required minimization and mitigation measures and to monitor compliance with and the effectiveness of the measures; and Issuance of the permit will not jeopardize the continued existence of a State-listed species."*

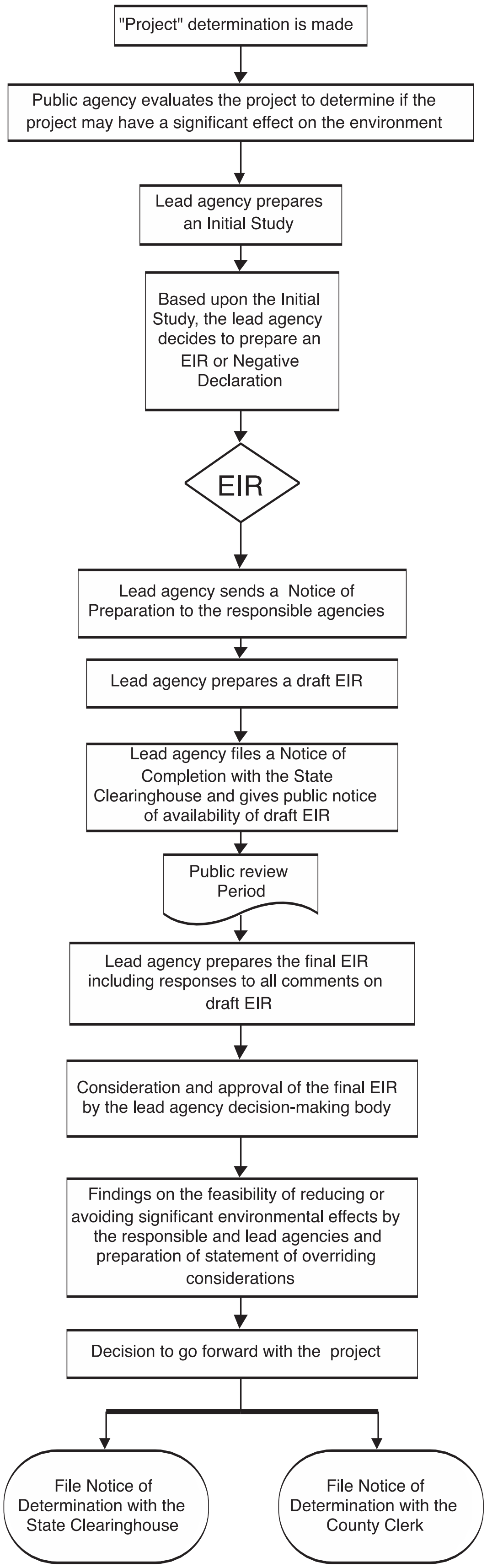
Fish and Game Code outlines the authority DFG has to protect and conserve natural resources within the state. The code has provisions for DFG authority under the CESA including regulatory authority for activities in channels, beds, and banks of lakes, rivers and streams.

Fully Protected Animals: Table 1 provides a complete list of animals with Fully Protected status.

Table 1. Fully Protected Animals.

COMMON NAME	SCIENTIFIC NAME
Fishes	
Colorado River squawfish (=Colorado pikeminnow)	*Ptychocheilus lucius*
thicktail chub	*Gila crassicauda*
Mohave chub (=Mohave tui chub)	*Gila mohavensis*
Lost River sucker	*Catostomus luxatus* (=*Deltistes luxatus*)
Modoc sucker	*Catostomus microps*
shortnose sucker	*Chasmistes brevirostris*
humpback sucker (=razorback sucker)	*Xyrauchen texanus*
Owens River pupfish (=Owens pupfish)	*Cyprinoden radiosus*
unarmored threespine stickleback	*Gasterosteus aculeatus williamsoni*
rough sculpin	*Cottus asperrimus*
Amphibians	
Santa Cruz long-toed salamander	*Ambystoma macrodactylum croceum*
limestone salamander	*Hydromantes brunus*
black toad	*Bufo exsul*
Reptiles	
blunt-nosed leopard lizard	*Gambelia sila* (=*Gambelia silus*)
San Francisco garter snake	*Thamnophis sirtalis tetrataenia*
Birds	
American peregrine falcon	*Falco peregrinus anatum*
brown pelican (=California brown pelican)	*Pelecanus occidentalis* (=*P. o. occidentalis*)
California black rail	*Laterallus jamaicensis coturniculus*
California clapper rail	*Rallus longirostris obsoletus*
California condor	*Gymnogyps califonianus*
California least tem	*Sterna albifrons browni* (=*Sterna antillarum browni*)
golden eagle	*Aquila chrysaetos*
greater sandhill crane	*Grus candadensis tabida*
light-footed clapper rail	*Rallus longirostris levipes*
southern bald eagle (=bald eagle)	*Haliaeetus leucocephalus leucocephalus* (=*Haliaeetus leucocephalus*)
trumpeter swan	*Cygnus buccinator*
white-tailed kite	*Elanus leucurus*
Yuma clapper rail	*Rallus longirostris yumanensis*
Mammals	
Morro Bay kangaroo rat	*Dipodomys heermanni morroensis*
bighorn sheep	*Ovis canadensis* - except Nelson bighorn sheep (*ssp. Ovis canadensis nelsoni*) in the area described in subdivision (b) of Section 4902 (Fish and Game Code)
northern elephant seal	*Mirounga angustirostris*
Guadalupe fur seal	*Arctocephalus townsendi*
ring-tailed cat	*Genus Bassariscus* (=*Bassariscus astutus*)
Pacific right whale	*Eubalanea sieboldi* (=*Balaena glacialis*)
salt-marsh harvest mouse	*Reithrodontomys raviventris*
southern sea otter	*Enhydra lutris nereis*
wolverine	*Gulo luscus* (=*Gulo gulo*)

Figure 1. CEQA Process.
Overview of the CEQA process



Adapted from CERES CEQA process flow chart.

STATE WATER RESOURCES CONTROL BOARD
BOARD MEETING SESSION—DIVISION OF WATER QUALITY
JULY 16, 2003

ITEM 9

SUBJECT

CONSIDERATION OF A RESOLUTION ADOPTING EMERGENCY REGULATIONS THAT ESTABLISH MINIMUM REQUIREMENTS FOR THE DESIGN, CONSTRUCTION, OPERATION, AND CLOSURE OF SOLAR EVAPORATORS AS COMPONENTS OF INTEGRATED ON-FARM DRAINAGE MANAGEMENT SYSTEMS

DISCUSSION

In 1990, the San Joaquin Valley Drainage Program recommended the implementation of sequential agricultural drainage reuse systems, now known as Integrated on-Farm Drainage Management (IFDM) systems, as one major component of a comprehensive agricultural drainage management plan to address the impact of poor quality shallow groundwater on now almost one million acres of agricultural land on the westside of the San Joaquin Valley. The plan recommended that 156,000 acres of tile-drained cropland be included in drainage reuse or IFDM systems by the year 2000 in the initial phase of the proposed 50-year plan to manage shallow groundwater and salinity in-valley and sustain productivity of agricultural lands. The recommendation was contained in *A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley*, popularly known as the Rainbow Report. In 1991, the State Water Resources Control Board (SWRCB) entered into a Memorandum of Understanding with seven other State and federal agencies to form the San Joaquin Valley Drainage Implementation Program (SJVDIP) for the purpose of implementing the recommendations of the Rainbow Report.

There are two types of evaporation systems currently used by farmers in the San Joaquin Valley to manage agricultural drainage water. The first are the large evaporation ponds in Tulare Lake Basin that receive and store drainage water directly from irrigated farmland without reuse. The second are the solar evaporators operated as part of an IFDM system. Agricultural drainage water is sequentially reused (one to three times) to irrigate salt-tolerant forage and other crops until the volume of drainage water is substantially decreased and its salt content significantly increased. The concentrated brine is then sprayed into an on-farm solar evaporator—a shallow basin that is the endpoint of the sequential reuse system. No off-farm discharge of drainage water occurs in this system. It has been proposed that crystallized salts from the solar evaporator be harvested as a commercial product; however, no markets have yet been established.

The first drainage reuse pilot project was initiated on a site near Mendota by the Westside Resource Conservation District in 1985, with the support of several State and federal government agencies. In 1994, work began on the development of a complete IFDM system for sequential drainage reuse at Red Rock Ranch in western Fresno County. Development of IFDM systems and solar evaporators has focused for the last nine years on Red Rock Ranch. The Red Rock Ranch prototype IFDM system has achieved significant improvements in root zone soil and water quality and crop productivity on about 76% of the farmed acreage, with substantial improvement in the productivity of high-value salt-sensitive crops. Productive reuse has been made of the drainage water collected on-farm for irrigating salt-tolerant forage, cotton, and other crops on another 23% of the IFDM system acreage.

A small solar evaporator was constructed as the salt end-point component of this IFDM system. Waste Discharge Requirements (WDR) for its operation were established by the Central Valley Regional Water Quality Control Board (CVRWQCB). However, naturally high selenium concentrations in the drainage discharged to the evaporator invoked regulatory provisions of the Toxic Pits Cleanup Act (TPCA 1984) and created difficulties in permitting the solar evaporator as the essential final component of the IFDM system. Red Rock Ranch experienced difficulty in efficiently operating the solar evaporator while meeting the WDR's and was served with Notices of Violation. Problems were associated with ponding sufficient to develop a growth of invertebrates (primarily brine flies) initiating a selenium-containing food chain that resulted in impacts to nesting shorebirds. The data for stilts nesting near the solar ~~pond~~ evaporator at Red l Rock Ranch represent the highest percent incidence of selenium-induced birth defects reported from field studies to date. These and other problems resulted in the cessation of operation of the original solar evaporator at the Ranch. Attempted solutions to resolve the conflict with TPCA were found to be impractical and infeasible.

Meanwhile, rising water tables and increasing soil salinity threaten root zone soil and water quality and continued productivity on westside San Joaquin Valley agricultural lands. To date, complete IFDM systems have been developed on only about 1600 acres of agricultural land. At the present time, other alternatives for the management of subsurface agricultural drainage, such as out-of-valley disposal of drainage to the Bay-Delta or Pacific Ocean, or discharge to large, conventional evaporation ponds, is either generally unavailable or infeasible. A number of growers on the westside of the San Joaquin Valley would like to institute complete IFDM systems with solar evaporators and resulting improvements in soil and water quality, but are reluctant to do so until the existing regulatory issues with respect to the Red Rock Ranch solar evaporator are resolved. Further, other growers and districts are instituting partial IFDM systems with salt-tolerant crop reuse components but with no solar evaporators as a salt endpoint. Incomplete IFDM systems without salt endpoints risk future loss of soil and water quality improvements, and impacts to wildlife.

This situation has placed the entire operation of IFDM systems and the future implementation of the Rainbow Report recommendations in question and led to the passage of Senate Bill (SB) 1372 in September, 2002. By this act, solar evaporators are exempt from the provisions of TPCA. Solar evaporators did not exist at the time of enactment of TPCA, and the provisions of TPCA do not take account of the unique circumstances and conditions pertinent to solar evaporators. SB 1372 also exempts solar evaporators from WDRs under the California Water Code, and requires the development of new emergency regulations specifically designed to address the environmental and operational conditions associated with solar evaporators, thereby facilitating the full development and completion of IFDM systems.

The new regulations establish minimum requirements for the design, construction, operation, and closure of solar evaporators and have been developed through a review of existing information on the development and regulation of solar evaporators, and through informal consultation with other State agencies, primarily the Department of Water Resources, and the Department of Food and Agriculture. Technical advice and recommendations were requested of the Department of Fish and Game and the U.S. Fish and Wildlife Service, as required by SB 1372. A fact finding field tour of existing and proposed solar evaporators was made in December, 2002, with meetings held with existing operators and prospective applicants. The tour included an innovative new solar evaporator design currently being developed and tested at Red Rock Ranch.

The new regulations closely follow the language and intent of SB 1372, adding clarity and specificity where needed or useful. Existing regulations in the California Code of Regulations are cited or referenced where appropriate. The new regulations are primarily designed to account for the no standing water provision of SB 1372. A specific definition of "standing water" has been developed based on limiting the potential for growth of brine flies that could result in biomagnification of selenium in a food chain. The "standing water" definition is thereby designed to provide adequate wildlife protection. Another important definition is "reasonably foreseeable operating conditions" that has been specified for both the design capacity of solar evaporator operating systems and natural occurrence of floods and incident rainfall. The definition of "water catchment basin" has been expanded to include a solar still or greenhouse as a fully contained component for the final separation and desiccation of salt. The new design and operation standards are intended to facilitate the development and implementation of solar evaporators as components of IFDM systems, while protecting avian wildlife and existing groundwater quality.

Adoption by the SWRCB of new solar evaporator emergency regulations has been determined by the Office of the Chief Counsel to be subject to an emergency exemption from the California Environmental Quality Act.

POLICY ISSUE

Should the SWRCB adopt emergency regulations (see attachment) that establish minimum requirements for the design, construction, operation, and closure of solar evaporators as components of IFDM systems in compliance with SB 1372?

FISCAL IMPACT

Annual costs of approximately $181,000 are anticipated for the (CVRWQCB) in FY 2003-2004, and $161,000 annually thereafter, to carry out the provisions of the new solar evaporator regulations. SB 1372 requires any Regional Water Quality Control Boards (RWQCBs) receiving a Notice of Intent to construct and operate a solar evaporator to review the application, inspect the site, identify additional data requirements, conduct facility inspections after construction, determine facility compliance with the requirements of the regulations, review annual monitoring data reports, and other tasks. Although the bill prohibits RWQCBs from approving new facilities after January 1, 2008, operation of facilities approved prior to that date would be allowed to continue and, therefore, would require continued regulatory effort by the RWQCBs. Funds from the existing Surface Impoundment Assessment Account in the General Fund (approximately $1.2 million) may be used for this purpose.

RWQCB IMPACT

Yes, mainly Central Valley Regional Water Quality Control Board.

STAFF RECOMMENDATION

Staff recommends adoption of emergency regulations that establish minimum requirements (see attachment) for the design, construction, operation, and closure of solar evaporators as components of IFDM systems in compliance with SB 1372.

STATE WATER RESOURCES CONTROL BOARD *June 16, 2003*

RESOLUTION NO. 2003-

AUTHORIZING A RESOLUTION ADOPTING EMERGENCY REGULATIONS THAT ESTABLISH MINIMUM REQUIREMENTS FOR THE DESIGN, CONSTRUCTION, OPERATION, AND CLOSURE OF SOLAR EVAPORATORS AS COMPONENTS OF INTEGRATED ON-FARM DRAINAGE MANAGEMENT (IFDM) SYSTEMS

WHEREAS:

1. The sustainability of approximately one million acres of productive agricultural land on the westside of the San Joaquin Valley is threatened by rising shallow groundwater of poor quality.
2. Recommended measures contained in *A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley*, to provide short-term agricultural drainage relief, include sequential drainage reuse or IFDM systems.
3. IFDM systems require an evaporation system as the final component for the separation and collection of salt.
4. The Legislature has found that IFDM is a sustainable system of managing salt-laden farm drainage water. IFDM is designed to eliminate the need for off-farm drainage of irrigation water, prevent the on-farm movement of irrigation and drainage water to groundwater, restore and enhance the productive value of degraded farmland by removing salt and selenium from the soil, conserve water by reducing the demand for irrigation water, and create the potential to convert salt from a waste product and pollutant to a commercial farm commodity.
5. The Legislature has found it is the policy of the state to conserve water and to minimize the environmental impacts of agricultural drainage. It is therefore in the interests of the state to encourage the voluntary implementation of sustainable farming and irrigation practices, including, but not limited to, IFDM as a means of improving environmental protection, conserving water, restoring degraded soils, and enhancing the economic productivity of farms.
6. The Legislature has directed the State Water Resources Control Board (SWRCB), on or before April 1, 2003, to adopt emergency regulations that establish minimum requirements for the design, construction, operation, and closure of solar evaporators. The SWRCB granted a delay in adoption as requested by other State agencies and stakeholders.
7. This action to adopt emergency solar evaporator regulations is exempt from the requirements of the California Environmental Quality Act pursuant to Public Resources Code section 21080(b)(4).
8. The SWRCB has developed new solar evaporator regulations in compliance with Senate Bill 1372 (SB 1372) to be located within California Code of Regulations Title 27, that facilitate the development and implementation of solar evaporators as components of IFDM systems, while protecting avian wildlife safety and groundwater quality.

THEREFORE BE IT RESOLVED THAT:

The State Water Resources Control Board adopts emergency regulations (see attachment) that establish minimum requirements for the design, construction, operation, and closure of solar evaporators as components of IFDM systems in compliance with SB 1372.

CERTIFICATION

The undersigned, Clerk to the Board, does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the State Water Resources Control Board held on July 16, 2003.

____

Debbie Irvin
Clerk to the Board

Revised 7/03/03

D R A F T

Title 27. Environmental Protection

Division 2. Solid Waste

Subdivision 1. Consolidated Regulations for Treatment, Storage, Processing, or Disposal of Solid Waste

Chapter 7. Special Treatment, Storage, and Disposal Units

Subchapter 6. Solar Evaporators

Article 1. Solar Evaporator Regulations

[Note: regulations in this article were promulgated by the State Water Resources Control Board (SWRCB), are administered by the appropriate Regional Water Quality Control Board (RWQCB), and are applicable to the owner or operator of a solar evaporator for the management of agricultural drainage water discharges from an integrated on-farm drainage management system (IFDM).]

§22900. SWRCB – Applicability.

(a) General—This article applies to the discharge of agricultural drainage water from Integrated On-Farm Drainage Management (IFDM) systems to solar evaporators as defined in §22910. No SWRCB-promulgated parts of the Division 2 of Title 27 and Division 3, Chapter 15 of Title 23 of the California Code of Regulations (CCR) shall apply to the discharge of agricultural drainage water from IFDM systems to solar evaporators unless those sections are specifically referenced in this article. Any person who intends to operate a solar evaporator after ~~July 1, 2003~~ [effective date] shall comply with the requirements of this article before a Notice of Plan Compliance and Notice of Authority to Operate (§25209.13 of Article 9.7 of the Health and Safety Code) will be issued by a Regional Water Quality Control Board (RWQCB).

§22910. SWRCB – Definitions.

For purposes of this article, the following terms have the following meanings:

(a) "Adequately protected" means that:
- (1) Avian wildlife have no access to standing water in a water catchment basin.
- (2) Standing water does not occur in a solar evaporator outside of a water catchment basin, under reasonably forseeable operating conditions.
- (3) The solar evaporator, including the water catchment basin, does not become a medium for the growth of aerial aquatic and semi-aquatic macro invertebrates that could become a harmful food source for avian wildlife, under reasonably forseeable operating conditions.

(b) "Agricultural drainage water" means surface drainage water or percolated irrigation water that is collected by subsurface drainage tiles placed beneath an agricultural field.

(c) "Avian Wildlife Biologist" means any State or federal agency biologist, ecologist, environmentalspecialist (or equivalent title) with relevant avian wildlife monitoring experience (as determined by the RWQCB), or any professional biologist, ecologist, environmental specialist (or equivalent title) possessing valid unexpired State and federal collecting permits for avian wildlife eggs.

(d) "Boundaries of the solar evaporator" or "boundaries of a solar evaporator" means the outer edge of the solar evaporator or any component of the solar evaporator, including, but not limited to, berms, liners, water catchment basins, windscreens, and deflectors.

(~~d~~e) "Certified Engineering Geologist" means a registered geologist, certified by the State of California, pursuant to section 7842 of the Business and Professions Code.

(~~e~~f) "Hydraulic conductivity" means the ability of natural and artificial materials to transmit water. The term is expressed as a measure of the rate of flow through a unit area cross-section of material. The unit of measure is cm/sec.

(~~f~~g) "Integrated on-farm drainage management system" means a facility for the on-farm management of agricultural drainage water that does all of the following:

(1) Reduces levels of salt and selenium in soil by the application of irrigation water to agricultural fields.

(2) Collects agricultural drainage water from irrigated fields and sequentially reuses that water to irrigate successive crops until the volume of residual agricultural drainage water is substantially decreased and its salt content significantly increased.

(3) Discharges the residual agricultural drainage water to an on-farm solar evaporator for evaporation and appropriate salt management.

(4) Eliminates discharge of agricultural drainage water outside the boundaries of the property or properties that produces the agricultural drainage water and that is served by the integrated onfarm drainage management system and the solar evaporator.

(~~g~~h) "Liner" means:

(1) a continuous layer of natural or artificial material, or a continuous membrane of flexible and durable artificial material, or a continuous composite layer consisting of a membrane of flexible artificial material directly overlying a layer of engineered natural material, which is installed beneath a solar evaporator, and which acts as a barrier to vertical water movement, and

(2) a material that has appropriate chemical and physical properties to ensure that the liner does not fail to contain agricultural drainage water because of pressure gradients, physical contact with the agricultural drainage water, chemical reactions with soil, climatic conditions, ultraviolet radiation (if uncovered), the stress of installation, and the stress of daily operation, and

(3) a material that has a minimum thickness of 40 mils (0.040 inches) for flexible artificial membranes or synthetic liners.

(4) The requirements of this definition are applicable only if a liner is used to meet the requirements of §22920(c).

(~~h~~i) "Nuisance" means anything which meets all of the following requirements:

(1) Is injurious to health, or is indecent or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property.

(2) Affects at the same time an entire community or neighborhood, or a considerable number of persons, although the extent of the annoyance or damage inflicted on individuals may be unequal.

(3) Occurs during, or as a result of, the treatment or disposal of wastes.

(~~i~~j) "On-farm" means within the boundaries of a property, geographically contiguous properties, or a portion of the property or properties, owned or under the control of a single owner or operator, that is used for the commercial production of agricultural commodities and that contains an IFDM system and a solar evaporator.

(~~j~~k) "Pollution" means an alteration of the quality of the waters of the state by waste to a degreewhich unreasonably affects either of the following:

(1) The waters for beneficial uses.

(2) Facilities which serve these beneficial uses.

(~~k~~l) "Reasonably foreseeable operating conditions" means:

(1) within the range of the design discharge capacity of the IFDM system and the authorized solar evaporator system as specified in the Notice of Plan Compliance and Notice of Authority to Operate (§25209.13 of Article 9.7 of the Health and Safety Code),

(2) precipitation up to and including the local 25-year, 24-hour storm, and

(3) floods with a 100-year return period. Operation of a solar evaporator in exceedance of design specifications is not covered by "reasonably foreseeable operating conditions," and therefore would constitute a violation of the Notice of Authority to Operate.

(~~l~~m) “Regional Board” and “RWQCB” means a California Regional Water Quality Control Board.

(~~m~~n) “Registered Agricultural Engineer” means an agricultural engineer registered by the State of California, pursuant to section 6732 of the Business and Professions Code.

(~~n~~o) “Registered Civil Engineer” means a civil engineer registered by the State of California, pursuant to section 6762 of the Business and Professions Code.

(~~o~~p) “Registered Geologist” means a geologist registered by the State of California, pursuant to section 7842 of the Business and Professions Code.

(~~p~~q) “Solar evaporator” means an on-farm area of land and its associated equipment that meets all of the following conditions:

(1) It is designed and operated to manage agricultural drainage water discharged from the IFDM system.

(2) The area of the land that makes up the solar evaporator is equal to, or less than, 2 percent of the area of the land that is managed by the IFDM system.

(3) Agricultural drainage water from the IFDM system is discharged to the solar evaporator by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water within the solar evaporator or, if a water catchment basin is part of the solar evaporator, within that portion of the solar evaporator that is outside the basin.

(4) The combination of the rate of discharge of agricultural drainage water to the solar evaporator and subsurface tile drainage under the solar evaporator provides adequate assurance that constituents in the agricultural drainage water will not migrate from the solar evaporator into the vadose zone or waters of the state in concentrations that pollute or threaten to pollute the waters of the state.

(~~q~~r) “Standing water” means water occurring under all of the following conditions:

(1) to a depth greater than one centimeter,

(2) for a continuous duration in excess of 48 hours,

(3) as a body of any areal extent, not an average depth, and

(4) under reasonably forseeable operating conditions.

(~~r~~s) “Subsurface drainage tiles” or “subsurface tile drainage” means any system of subsurface drainage collection utilizing drainage tiles, perforated pipe, or comparable conveyance, placed below the surface of any IFDM system area including the solar evaporator.

(~~s~~t) “Unreasonable threat” to avian wildlife means that avian wildlife is not adequately protected.

(~~t~~u) “Vadose zone” means the unsaturated zone between the soil surface and the permanent groundwater table.

(~~u~~v) “Water catchment basin” means an area within the boundaries of a solar evaporator that is designated to receive and hold any water that might otherwise be standing water within the solar evaporator. The entire area of a water catchment basin shall be permanently and continuously covered with netting, or otherwise designed, constructed, and operated to prevent access by avian wildlife to standing water within the basin. A water catchment basin may include an enclosed solar still, greenhouse or other fully contained drainage storage unit. For the purposes of this definition, the term “within the boundaries of a solar evaporator” shall include a solar still, greenhouse, or other fully contained drainage storage unit adjacent to or near the portion of the solar evaporator that is outside the catchment basin.

(~~u~~w) “Waters of the state” means any surface water or groundwater, including saline water, within the boundaries of the state.

§22920. SWRCB – Solar Evaporator Design Requirements.

(a) Registered Professionals – Solar evaporators shall be designed by a registered civil or agricultural engineer, or a registered geologist or certified engineering geologist.

(b) Flooding – A solar evaporator shall be located outside the 100-year floodplain, or shall be constructed with protective berms/levees sufficient to protect the solar evaporator from overflow and inundation by 100-year floodwaters, or shall be elevated above the maximum elevation of a 100-year flood.

(c) Protection of Groundwater Quality – Solar evaporators shall be immediately underlain by at least 1 meter of soil with a hydraulic conductivity of not more than 1 x 10-6 cm/sec above the zone of shallow groundwater at any time during the year. The surface of the solar evaporator shall be a minimum of five-feet (5 ft.) above the highest anticipated elevation of underlying groundwater. A solar evaporator may be constructed on a site with soils that do not meet the above requirement, with subsurface tile drainage under or directly adjacent to the solar evaporator, a liner, or other engineered alternative, sufficient to provide assurance of the equivalent level of groundwater quality protection of the above soil requirement.

(d) Discharge to the Facility – All discharge to the solar evaporator shall be agricultural drainage water collected from the IFDM system or recirculated from the solar evaporator as a component of the IFDM system. No agricultural drainage water from the IFDM system or the solar evaporator may be discharged outside the boundaries of ~~the area of land that makes up~~ the solar evaporator

(e) Facility Size – The area of land that makes up the solar evaporator may not exceed 2 percent of the area of land that is managed by the IFDM system.

(f) Means of Discharge to the Facility – Discharge of agricultural drainage water from the IFDM system to the solar evaporator shall be by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water in the solar evaporator, outside a water catchment basin. The sprinklers shall be equipped with screens or shields or other devices as necessary to prevent the drift of agricultural drainage water spray outside the boundaries of the solar evaporator.

(g) Water Catchment Basin – A water catchment basin may be required:

(1) As a component of a solar evaporator if standing water would otherwise occur within the solar evaporator under reasonably foreseeable operating conditions, or

(2) If a solar evaporator is constructed with a liner. In this case, a water catchment basin shall be designed with the capacity to contain the maximum volume of water that the solar evaporator would collect under reasonably forseeable operating conditions. A water catchment basin is not required for a solar evaporator that does not have a liner, if it is demonstrated that standing water will not occur under reasonably foreseeable operating conditions.

(h) Avian Wildlife Protection – The solar evaporator shall be designed to ensure that avian wildlife is adequately protected as set forth in §22910 (a) and (~~u~~v).

§22930. SWRCB – Solar Evaporator Construction Requirements.

(a) Registered Professionals – Construction of solar evaporators shall be supervised and certified, by a registered civil or agricultural engineer, or a registered geologist or certified engineering geologist, as built according to the design requirements and Notice of Plan Compliance (§25209.13 of Article 9.7 of the Health and Safety Code).

§22940. SWRCB – Solar Evaporator Operation Requirements.

(a) Limitation on Standing Water – The solar evaporator shall be operated so that, under reasonably forseeable operating conditions, the discharge of agricultural drainage water to the solar evaporator will not result in standing water, outside of a water catchment basin. Agricultural drainage water from the IFDM system shall be discharged to the solar evaporator by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water in the solar evaporator.

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(b) Prevention of Nuisance – The solar evaporator shall be operated so that, under reasonably forseeable operating conditions, the discharge of agricultural drainage water to the solar evaporator does not result in:
(1) The drift of salt spray, mist, or particles outside of the boundaries of the solar evaporator, or
(2) Any other nuisance condition.

(c) Prohibition of Outside Discharge – The operation of a solar evaporator shall not result in any discharge of agricultural drainage water outside the boundaries of ~~the area of land that makes up~~ the solar evaporator.

(d) Salt Management – For solar evaporators in continuous operation under a Notice of Authority to Operate issued by a Regional Water Quality Control Board, evaporite salt accumulated in the solar evaporator shall be collected and removed from the solar evaporator if and when the accumulation is sufficient to interfere with the effectiveness of the operation standards of the solar evaporator as specified in this section. One of the following three requirements shall be selected and implemented by the owner or operator:
(1) Evaporite salt accumulated in the solar evaporator may be harvested and removed from the solar evaporator and sold or utilized for commercial, industrial, or other beneficial purposes.
(2) Evaporite salt accumulated in the solar evaporator may be stored for a period of one-year, renewable subject to an annual inspection, in a fully contained storage unit inaccessible to wind, water, and wildlife, until sold, utilized in a beneficial manner, or disposed in accordance with (3).
(3) Evaporite salt accumulated in the solar evaporator may be collected and removed from the solar evaporator, and disposed permanently as a waste in a facility authorized to accept such waste in compliance with the requirements of Titles 22, 23, 27 and future amendments of the CCR, or Division 30 (commencing with Section 40000) of the Public Resources Code.

(e) Monitoring – Monitoring and record keeping, including a groundwater monitoring schedule, data, and any other information or reporting necessary to ensure compliance with this article, shall be established by the RWQCB in accord with §25209.14 of Article 9.7 of the Health and Safety Code.

(f) Avian Wildlife Protection – The solar evaporator shall be operated to ensure that avian wildlife is adequately protected as set forth in §22910 (a) and (~~u~~v). The following Best Management Practices are required:
(1) Solar evaporators (excluding water catchment basins) shall be kept free of all vegetation.
(2) Grit-sized gravel (<5 mm in diameter) shall not be used as a surface substrate within the solar evaporator.
(3) Netting or other physical barriers for excluding avian wildlife from water catchment basins shall not be allowed to sag into any standing water within the catchment basin.
(4) The emergence and dispersal of aerial aquatic and semi-aquatic macro invertebrates or aquatic plants outside of the boundary of the water catchment basin shall be prevented.
(5) The emergence of the pupae of aerial aquatic and semi-aquatic macro invertebrates from the water catchment basin onto the netting, for use as a pupation substrate, shall be prevented.

(g) Inspection – The RWQCB issuing a Notice of Authority to Operate a solar evaporator shall conduct authorized inspections in accord with §25209.15 of Article 9.7 of the Health and Safety Code to ensure continued compliance with the requirements of this article. The RWQCB shall request an avian wildlife biologist to assist the RWQCB in its inspection of each authorized solar evaporator at least once annually during the month of May. If an avian wildlife biologist is not available, the RWQCB shall nevertheless conduct the inspection. During the inspection, observations shall be made for compliance with §22910 (a) and (uv), and the following conditions that indicate an unreasonable threat to avian wildlife:
(1) Presence of vegetation within the ~~perimeter~~ boundaries of the solar evaporator;

(2) Standing water or other mediums within the solar evaporator that support the growth and dispersal of aerial aquatic or semi-aquatic macro invertebrates or aquatic plants;
(3) Abundant sustained avian presence within the solar evaporator that could result in nesting activity;
(4) An apparent avian die-off or disabling event within the solar evaporator;
(5) Presence of active avian nests with eggs within the ~~perimeter~~ <u>boundaries</u> of the solar evaporator.

If active avian nests with eggs are found within the ~~perimeter~~ <u>boundaries</u> of the solar evaporator, the RWQCB shall report the occurrence to the USFWS and DFG within 24 hours, and seek guidance with respect to applicable wildlife laws and implementing regulations. Upon observation of active avian nests with eggs within the ~~perimeter~~ <u>boundaries</u> of the solar evaporator, all discharge of agricultural drainage water to the solar evaporator shall cease until (a) the nests are no longer active, or (b) written notification is received by the owner or operator, from the RWQCB, waiving the prohibition of discharge in compliance with all applicable state and federal wildlife laws and implementing regulations (i.e., as per applicable exemptions and allowable take provisions of such laws and implementing regulations.)

§22950. SWRCB – Solar Evaporator Closure Requirements.

(a) For solar evaporators ceasing operation through discontinuance of operation or non-renewal of a Notice of Authority to Operate issued by a RWQCB, closure and post-closure plans shall be prepared and submitted to the RWQCB and approved by the RWQCB prior to closure. Closure plans shall conform to one of the following three requirements to be selected and implemented by the owner or operator:

(1) Evaporite salt accumulated in the solar evaporator may be harvested and removed from the solar evaporator and sold or utilized for commercial, industrial, or other beneficial purposes or stored for a period of one-year, renewable subject to an annual inspection, in a fully contained storage unit inaccessible to wind, water, and wildlife, until sold, utilized in a beneficial manner, or disposed in accordance with (3). After the removal of accumulated salt, the area within the boundaries of the solar evaporator shall be restored to a condition that does not pollute or threaten to pollute the waters of the state, that does not constitute an unreasonable threat to avian wildlife, and that does not constitute a nuisance condition. Clean closure may be accomplished in accord with §21090(f) and §21400 of CCR Title 27.
(2) The solar evaporator may be closed in-place, with installation of a final cover with foundation, low-hydraulic conductivity, and erosion-resistant layers, as specified in §21090 and §21400 of CCR Title 27. Closure in-place shall include a closure plan and post-closure cover maintenance plan in accord with §21090 and §21769 of CCR Title 27.
(3) Evaporite salt accumulated in the solar evaporator may be collected and removed from the solar evaporator, and disposed permanently as a waste in a facility authorized to accept such waste in compliance with the requirements of Titles 22, 23, 27 and future amendments of the CCR, or Division 30 (commencing with Section 40000) of the Public Resources Code. After the removal of accumulated salt, the area within the boundaries of the solar evaporator shall be restored to a condition that does not pollute or threaten to pollute the waters of the state, that does not constitute an unreasonable threat to avian wildlife, and that does not constitute a nuisance condition.

Senate Bill No. 1372

CHAPTER 597

An act to amend Section 25208.3 of, and to add Article 9.7 (commencing with Section 25209.10) to Chapter 6.5 of Division 20 of, the Health and Safety Code, relating to water.

[Approved by Governor September 15, 2002.
Filed with Secretary of State September 16, 2002.]

LEGISLATIVE COUNSEL'S DIGEST

SB 1372, Machado. State Water Resources Control Board: agricultural drainage: solar evaporators.

(1) Under the Agricultural Water Conservation and Management Act, water suppliers, as defined, individually, or in cooperation with other public agencies or persons, may institute a water conservation or efficient water management program consisting of farm and agricultural related components. Existing law, the Toxic Pits Cleanup Act of 1984, prohibits a person from discharging liquid hazardous wastes into a surface impoundment if the surface impoundment, or the land immediately beneath the impoundment, contains hazardous wastes and is within 1/2 mile upgradient from a potential source of drinking water.

This bill would require the State Water Resources Control Board to adopt, on or before April 1, 2003, emergency regulations that establish minimum requirements for the design, construction, operation, and closure of solar evaporators, as defined. The bill would require any person who intends to operate a solar evaporator to file a notice of intent with the regional water quality control board. The bill would specify a procedure for the issuance of a notice of authority by the regional board to operate a solar evaporator, including requiring the regional board to inspect the solar evaporator prior to authorizing the operation of the solar evaporator. The bill would prohibit a regional board from issuing a notice of authority to operate a solar evaporator on and after January 1, 2008.

The bill would require any person operating a solar evaporator to submit annually, according to a schedule established by the regional board, groundwater monitoring data and other information deemed necessary by the regional board. The bill would require the regional board to inspect any solar evaporator at least once every 5 years to ensure continued compliance with the provisions of the bill.

The bill would exempt any solar evaporator operating under a valid written notice of authority to operate issued by the regional board, including any facility that the regional board determines is in compliance with the requirements of the bill, from the provisions of the toxic pits act and other specified waste discharge requirements imposed under the Porter-Cologne Water Quality Control Act.

Because the provisions added by the bill would be located within the hazardous waste control laws and a violation of those laws is a crime, the bill would impose a state-mandated local program by creating new crimes regarding the operation of solar evaporators.

(2) Existing law, the toxic pits act, requires the state board to impose a fee upon any person discharging any liquid hazardous waste or hazardous waste containing free liquids into a surface impoundment. The state board is required to collect and deposit the fees in the Surface Impoundment Assessment Account in the General Fund. The money within that account is available, upon appropriation, to the state board and the regional boards for purposes of administering the toxic pits act.

This bill would additionally authorize the board to expend the fees deposited in the account for the purpose of administering the surface impoundments that would be exempted from the toxic pits act by the bill, thereby imposing a tax for purposes of Article XIII A of the California Constitution.

(3) The California Constitution requires the state to reimburse local agencies and school districts for certain costs mandated by the state. Statutory provisions establish procedures for making that reimbursement.

This bill would provide that no reimbursement is required by this act for a specified reason.

The people of the State of California do enact as follows:

SECTION 1. Section 25208.3 of the Health and Safety Code is amended to read:

25208.3. (a) The state board shall, by emergency regulation, adopt a fee schedule that assesses a fee upon any person discharging any liquid hazardous wastes or hazardous wastes containing free liquids into a surface impoundment, except as provided in Section 25208.17. The state board shall include in this fee schedule the fees charged for applications for, and renewals of, an exemption from Section 25208.5, as specified in subdivision (h) of Section 25208.5, from subdivision (a) of Section 25208.4, as specified in subdivision (b) of Section 25208.4, from subdivision (c) of Section 25208.4, as specified in Section 25208.16, and from Sections 25208.4 and 25208.5, as specified in subdivision (e) of Section 25208.13. The state board shall also include provisions in the fee schedule for assessing a penalty pursuant to subdivision (c). The state board shall set these fees at an amount equal to the state board's and regional board's reasonable and anticipated costs of administering this article.

(b) The emergency regulations that set the fee schedule shall be adopted by the state board in accordance with Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, and for the purposes of that chapter, including Section 11349.6 of the Government Code, the adoption of these regulations is an emergency and shall be considered by the Office of Administrative Law as necessary for the immediate preservation of the public peace, health and safety, and general welfare. Notwithstanding Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, any emergency regulations adopted by the state board pursuant to this section shall be filed with, but not be repealed by, the Office of Administrative Law and shall remain in effect until revised by the state board.

(c) The state board shall send a notice to each person subject to the fee specified in subdivision (a). If a person fails to pay the fee within 60 days after receipt of this notice, the state board shall require the person to pay an additional penalty fee. The state board shall set the penalty fee at not more than 100 percent of the assessed fee, but in an amount sufficient to deter future noncompliance, as based upon that person's past history of compliance and ability to pay, and upon additional expenses incurred by this noncompliance.

(d) The state board shall collect and deposit the fees collected pursuant to this article in the Surface Impoundment Assessment Account, which is hereby created in the General Fund. The money within the Surface Impoundment Assessment Account is available, upon appropriation by the Legislature, to the state board and the regional boards for purposes of administering this article and Article 9.7 (commencing with Section 25209.10).

SEC. 2. Article 9.7 (commencing with Section 25209.10) is added to Chapter 6.5 of Division 20 of the Health and Safety Code, to read:

Article 9.7. Integrated On-Farm Drainage Management

25209.10. The Legislature finds and declares all of the following:

(a) The long-term economic and environmental sustainability of agriculture is critical to the future of the state, and it is in the interest of the state to enact policies that enhance that sustainability.

(b) High levels of salt and selenium are present in many soils in the state as a result of both natural occurrences and irrigation practices that concentrate their presence in soils.

(c) The buildup of salt and selenium in agricultural soil is an unsustainable practice that degrades soil, harms an irreplaceable natural resource, reduces crop yields and farm income, and poses threats to wildlife.

(d) Salt and selenium buildup can degrade groundwater, especially in areas with perched groundwater aquifers.

(e) Off-farm drainage of irrigation water with high levels of salt and selenium degrades rivers and waterways, particularly the San Joaquin River and its tributaries. This environmental damage presents a clear and imminent danger that warrants immediate action to prevent or mitigate harm to public health and the environment.

(f) Discharge of agricultural drainage water to manmade drains and ponds has resulted in environmental damage, including damage to wildlife. Proposals to discharge agricultural drainage to natural water bodies, including the San Francisco Bay, are extremely expensive and pose threats to the environmental quality of those water bodies.

(g) Water supplies for agricultural irrigation have been reduced significantly in recent years, necessitating increased efforts to use water more efficiently.

(h) Although salt can be collected and managed as a commercial farm commodity, California currently imports salt from other countries.

(i) Integrated on-farm drainage management is a sustainable system of managing salt-laden farm drainage water. Integrated on-farm drainage management is designed to eliminate the need for off-farm drainage of irrigation water, prevent the on-farm movement of irrigation and drainage water to groundwater, restore and enhance the productive value of degraded farmland by removing salt and selenium from the soil, conserve water by reducing the demand for irrigation water, and create the potential to convert salt from a waste product and pollutant to a commercial farm commodity.

(j) Although integrated on-farm drainage management facilities are designed and operated expressly to prevent threats to groundwater and wildlife, these facilities currently may be classified as surface impoundments pursuant to the Toxic Pits Act of 1984, which discourages farmers from using them as an environmentally preferable means of managing agricultural drainage water.

(k) It is the policy of the state to conserve water and to minimize the environmental impacts of agricultural drainage. It is therefore in the interest of the state to encourage the voluntary implementation of sustainable farming and irrigation practices, including, but not limited to, integrated on-farm drainage management, as a means of improving environmental protection, conserving water, restoring degraded soils, and enhancing the economic productivity of farms.

25209.11. For purposes of this article, the following terms have the following meanings:

(a) "Agricultural drainage water" means surface drainage water or percolated irrigation water that is collected by subsurface drainage tiles placed beneath an agricultural field.

(b) "On-farm" means within the boundaries of a property, geographically contiguous properties, or a portion of the property or properties, owned or under the control of a single owner or operator, that is used for the commercial production of agricultural commodities and that contains an integrated on-farm drainage management system and a solar evaporator.

(c) "Integrated on-farm drainage management system" means a facility for the on-farm management of agricultural drainage water that does all of the following:

(1) Reduces levels of salt and selenium in soil by the application of irrigation water to agricultural fields.

(2) Collects agricultural drainage water from irrigated fields and sequentially reuses that water to irrigate successive crops until the volume of residual agricultural drainage water is substantially decreased and its salt content significantly increased.

(3) Discharges the residual agricultural drainage water to an on-farm solar evaporator for evaporation and appropriate salt management.

(4) Eliminates discharge of agricultural drainage water outside the boundaries of the property or properties that produces the agricultural drainage water and that is served by the integrated on-farm drainage management system and the solar evaporator.

(d) "Regional board" means a California regional water quality control board.

(e) "Solar evaporator" means an on-farm area of land and its associated equipment that meets all of the following conditions:

(1) It is designed and operated to manage agricultural drainage water discharged from the integrated on-farm drainage management system.

(2) The area of the land that makes up the solar evaporator is equal to, or less than, 2 percent of the area of the land that is managed by the integrated on-farm drainage management system.

(3) Agricultural drainage water from the integrated on-farm drainage management system is discharged to the solar evaporator by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water within the solar evaporator or, if a water catchment basin is part of the solar evaporator, within that portion of the solar evaporator that is outside the basin.

(4) The combination of the rate of discharge of agricultural drainage water to the solar evaporator and subsurface tile drainage under the solar evaporator provides adequate assurance that constituents in the

agricultural drainage water will not migrate from the solar evaporator into the vadose zone or waters of the state in concentrations that pollute or threaten to pollute the waters of the state.

(f) "State board" means the State Water Resources Control Board.

(g) "Water catchment basin" means an area within the boundaries of a solar evaporator that is designated to receive and hold any water that might otherwise be standing water within the solar evaporator. The entire area of a water catchment basin shall be permanently and continuously covered with netting, or otherwise designed, constructed, and operated to prevent access by avian wildlife to standing water within the basin.

25209.12. On or before April 1, 2003, the state board, in consultation, as necessary, with other appropriate state agencies, shall adopt emergency regulations that establish minimum requirements for the design, construction, operation, and closure of solar evaporators. The regulations shall include, but are not limited to, requirements to ensure all of the following:

(a) The operation of a solar evaporator does not result in any discharge of on-farm agricultural drainage water outside the boundaries of the area of land that makes up the solar evaporator.

(b) (1) The solar evaporator is designed, constructed, and operated so that, under reasonably forseeable operating conditions, the discharge of agricultural water to the solar evaporator does not result in standing water.

(2) Notwithstanding paragraph (1), a solar evaporator may be designed, constructed, and operated to accommodate standing water, if it includes a water catchment basin.

(3) The board may specify those conditions under which a solar evaporator is required to include a water catchment basin to prevent standing water that would otherwise occur within the solar evaporator.

(c) Avian wildlife is adequately protected. In adopting regulations pursuant to this subdivision, the state board shall do the following:

(1) Consider and, to the extent feasible, incorporate best management practices recommended or adopted by the United States Fish and Wildlife Service.

(2) Establish guidelines for the authorized inspection of a solar evaporator by the regional board pursuant to Section 25209.15. The guidelines shall include technical advice developed in consultation with the Department of Fish and Game and the United States Fish and Wildlife Service that may be used by regional board personnel to identify observed conditions relating to the operation of a solar evaporator that indicate an unreasonable threat to avian wildlife.

(d) Constituents in agricultural drainage water discharged to the solar evaporator will not migrate from the solar evaporator into the vadose zone or the waters of the state in concentrations that pollute or threaten to pollute the waters of the state.

(e) Adequate groundwater monitoring and recordkeeping is performed to ensure compliance with the requirements of this article.

(f) Salt isolated in a solar evaporator shall be managed in accordance with all applicable laws and shall eventually be harvested and sold for commercial purposes, used for beneficial purposes, or stored or disposed in a facility authorized to accept that waste pursuant to this chapter or Division 30 (commencing with Section 40000) of the Public Resources Code.

25209.13. (a) Any person who intends to operate a solar evaporator shall, before installing the solar evaporator, file a notice of intent with the regional board, using a form prepared by the regional board. The form shall require the person to provide information including, but not limited to, all of the following:

(1) The location of the solar evaporator.

(2) The design of the solar evaporator and the equipment that will be used to operate it.

(3) The maximum anticipated rate at which agricultural drainage water will be discharged to the solar evaporator.

(4) Plans for operating the solar evaporator in compliance with the requirements of this article.

(5) Groundwater monitoring data that are adequate to establish baseline data for use in comparing subsequent data submitted by the operator pursuant to this article.

(6) Weather data and a water balance analysis sufficient to assess the likelihood of standing water occurring within the solar evaporator.

(b) The regional board shall, within 30 calendar days after receiving the notice submitted pursuant to subdivision (a), review its contents, inspect, if necessary, the site where the proposed solar evaporator will be located, and notify the operator of the proposed solar evaporator whether it will comply with the requirements of this article. If the regional board determines that the proposed solar evaporator will not comply with this article, the regional board shall issue a written response to the applicant identifying the reasons for noncompliance. If the regional board determines the solar evaporator will comply with the requirements of this article, the regional board shall issue a written notice of plan compliance to the operator of the proposed solar evaporator.

(c) Any person who receives a written notice of plan compliance pursuant to subdivision (b) shall, before operating the installed solar evaporator, request the regional board to conduct a compliance inspection of the solar evaporator. Within 30 calendar days after receiving a request, the regional board shall inspect the solar evaporator and notify the operator whether it complies with the requirements of this article. If the regional board finds that the solar evaporator does not comply with the requirements of this article, the regional board shall issue a written response to the applicant identifying the reasons for noncompliance. Except as provided in subdivision (e), if the regional board determines that the solar evaporator complies with the requirements of this article, the regional board shall issue a written notice of authority to operate to the operator of the solar evaporator. The regional board may include in the authority to operate any associated condition that the regional board deems necessary to ensure compliance with the purposes and requirements of this article.

(d) No person may commence the operation of a solar evaporator unless the person receives a written notice of authority to operate the solar evaporator pursuant to this section.

(e) (1) On and after January 1, 2008, a regional board may not issue a written notice of authority to operate a solar evaporator pursuant to this section.

(2) The requirements of paragraph (1) do not affect the validity of any written notice of authority to operate a solar evaporator issued by the regional board before January 1, 2008.

(f) The regional board shall review any authority to operate issued by the regional board pursuant to this section every five years. The regional board shall renew the authority to operate, unless the regional board finds that the operator of the solar evaporator has not demonstrated compliance with the requirements of this article.

25209.14. (a) Any person operating a solar evaporator shall annually, according to a schedule established by the regional board pursuant to subdivision (b), submit groundwater monitoring data and any other information that is deemed necessary by the regional board to ensure compliance with the requirements of this article.

(b) Each regional board shall adopt a schedule for the submission of the data and information described in subdivision (a) at the earliest possible time. The regional board shall notify the operator of each solar evaporator of the applicable submission schedule.

25209.15. (a) The regional board, consistent with its existing statutory authority, shall inspect any solar evaporator that is authorized to operate pursuant to Section 25209.13 at least once every five years to ensure continued compliance with the requirements of this article. In conducting any inspection, the regional board may request the participation of a qualified state or federal avian biologist in a technical advisory capacity. The regional board shall include in the inspection report conducted pursuant to this section any evidence of adverse impacts on avian wildlife and shall forward the report to the appropriate state and federal agencies.

(b) If the regional board, as a result of an inspection or review conducted pursuant to this article, determines that a solar evaporator is not in compliance with the requirements of this article, the regional board shall provide written notice to the operator of the solar evaporator of that failure, and shall include in that written notice the reasons for that determination.

(c) Chapter 5 (commencing with Section 13300) of, and Chapter 5.8 (commencing with Section 13399) of, Division 7 of the Water Code apply to any failure to comply with the requirements of this article and to any action, or failure to act, by the state board or a regional board. The regional board may, consistent with Section 13223 of the Water Code, revoke or modify an authorization to operate issued pursuant to this article.

25209.16. (a) For the purposes of Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of

Title 2 of the Government Code, including Section 11349.6 of the Government Code, the adoption of the regulations required to be adopted pursuant to Section 25209.12 is an emergency and shall be considered by the Office of Administrative Law as necessary for the immediate preservation of the public peace, health and safety, and general welfare.

(b) Notwithstanding Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, any emergency regulations adopted by the state board pursuant to Section 25209.12 shall be filed with, but not be repealed by, the Office of Administrative Law and shall remain in effect until revised by the state board.

25209.17. Any solar evaporator operating under a valid written notice of authority to operate issued by the regional board pursuant to this article, including any facility operating pursuant to Article 9.5 (commencing with Section 25208) prior to January 1, 2003, that the regional board determines is in compliance with the requirements of this article, is not subject to Article 9.5 (commencing with Section 25208) or Sections 13260 or 13263 of the Water Code. Upon determining pursuant to this section that a facility is a solar evaporator in compliance with this article, the regional board shall, as appropriate, revise or rescind any waste discharge requirements or other requirements imposed on the operator of the facility pursuant to Article 9.5 (commencing with Section 25208) or Section 13260 or 13263 of the Water Code.

SEC. 3. No reimbursement is required by this act pursuant to Section 6 of Article XIII B of the California Constitution because the only costs that may be incurred by a local agency or school district will be incurred because this act creates a new crime or infraction, eliminates a crime or infraction, or changes the penalty for a crime or infraction, within the meaning of Section 17556 of the Government Code, or changes the definition of a crime within the meaning of Section 6 of Article XIII B of the California Constitution.

California Regional Water Quality Control Board
Central Valley Region

NOTICE OF INTENT

TO COMPLY WITH THE CONDITIONS OF ARTICLE 9.7.
Commencing with Section 25209.10 of the Health and Safety Code
Integrated On-Farm Drainage Management

FACILITY

A. NAME OF FACILITY OR BUSINESS OPERATING THE FACILITY:____

ADDRESS OF FACILITY: ____
Number and Street City Zip Code

COUNTY:____

CONTACT PERSON:_______________________________ TELEPHONE NO.______________________________

B. NAME OF LEGAL OWNER OF FACILITY:____

ADDRESS OF LEGAL OWNER OF FACILITY:____
Number and Street City Zip Code

CONTACT PERSON:_______________________________ TELEPHONE NO.______________________________

C. NAME OF CONTACT PERSON TO RECEIVE REGIONAL BOARD CORRESPONDENCE:__________________________

ADDRESS OF CONTACT PERSON:____
Number and Street City Zip Code

TELEPHONE NO. OF CONTACT PERSON: ______________________________

LOCATION OF SOLAR EVAPORATOR

NUMBER OF ACRES ________ SECTION ____, TOWNSHIP ____, RANGE ____. APN __________ COUNTY ________

Provide a map of the area of the complete IFDM system (including irrigated fields for reuse) and indicate location of solar evaporator, tile lines, and monitoring wells.

DESIGN OF SOLAR EVAPORATOR

Provide a technical report prepared by an appropriately-registered California professional for the design of the solar evaporator. The report should describe of the capacity and the equipment to operate the solar evaporator. Explain features to prevent inundation from a 100-year flood. Include the tile drain design and the soil properties such as permeability, grain size distribution, percent clay, etc.
MAXIMUM ANTICIPATED RATE OF DISCHARGE TO THE SOLAR EVAPORATOR _________

OPERATIONAL PLANS FOR COMPLIANCE

Provide a plan for compliance with the requirements of article 9.7. Plans must include measures to prevent standing water, mitigate wildlife impacts, and prevent migration of constituents from the solar evaporator into the vadose zone. Include weather data and a water balance sufficient to assess the likelihood of standing water, and supporting the design of the solar evaporator.

CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA) COMPLIANCE

HAS ANY CEQA DOCUMENT BEEN ADOPTED/CERTIFIED BY A LEAD AGENCY FOR THIS PROJECT?
______YES ______NO (IF YES, PLEASE ENCLOSE A COPY OF THE ADOPTION/CERTIFICATION)

IF NO, WILL ANY CEQA DOCUMENT BE PREPARED? ______YES ______NO

IF YES, WHO WILL PREPARE THE CEQA DOCUMENT? ____

APPROXIMATE DATE OF COMPLETION____________________

CERTIFICATION

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Atmospheric Salt Emissions from the Concentration of Agricultural Drainage Water by Sprinkler Evaporator

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Abstract

The Integrated On-Farm Drainage Management system that is being developed for use on the Westside of the San Joaquin Valley uses a solar evaporator as the final disposal mechanism for the salt laden water. The solar evaporator works by circulating the water through a network of horizontal fan sprinklers placed close to the ground. The effect of using these sprinklers is that evaporation is increased, but salt particulate is entrained in the air and carried away from the perimeter of the solar evaporator. The study developed a method to quantify the deposition flux downwind of the solar evaporator. The deposition downwind of the system was quantified for multiple sprinkler heights, and water sources and regression lines fit to the deposition to have a more complete understanding of the extent of the effects downwind of the system. Although no statistically significant differences were found between the regression lines, it was possible to accurately determine the deposition fluxes out to a distance of approximately 200 meters. At that point there was minimal difference between the measured deposition flux and background levels.

The salt particle loss rate from the solar evaporator during normal operation is approximately 1 kg/hr. Nearly all of that is deposited on the surface 200 meters or less from the source. The salt particles small enough to be carried beyond that point may be small enough to be regulated as PM_{10} but are such a small fraction of the total that they are 10 to 100 times less than the regulation threshold.

Conclusions

The universal constant in all sampling dates is that there is a significant drop in deposition rates as the radius increases close to the system with less chance as distance increases. This leads to the law of diminishing returns when deciding what an appropriate buffer zone around the system would be. It is clear that at 200 meters downwind of the source there is insignificant salt deposition during normal operating periods (evaporation of sump water). Although operation during the highest source strength did yield some measurable deposition at that distance, the frequency of operation in these conditions is minimal. Therefore, 200 meters appears to be the maximum amount of buffer needed downwind of the solar evaporator to prevent significant deposition from occurring on sensitive crops. It may be decided that some salt deposition is acceptable on the crop in that area and the distance could be reduced to 100 meters. This decision will depend on the crop that is planted in this area and its specific tolerance to salt deposition.

Operation of the solar evaporator with the fence in place decreases the total emissions of particles by interfering with the wind pattern at sprinkler level, thus reducing particle entrainment as well as intercepting some of the emissions before they leave the system perimeters. The fence also increases the effective emission height, thus increasing the dispersion of the plume. This will lead to higher deposition close to the solar evaporator, tailing off at a higher rate.

Analysis of the plume of salt dispersion and deposition was only conducted on the south and east sides of the solar evaporator because the prevailing wind at the site is constant from the Northwest. There should be some consideration given to a buffer zone completely surrounding the facility if the system is to be operated where the wind is more variable.

The particle emissions from the operation of the solar evaporator are a combination of those that are large enough to be deposited on the soil surface within the downwind plume and those that are small enough to remain entrained in the air. The small particles are those that could subject the solar evaporator facility to air quality regulations related to PM standards.

1. The re-deposition of salt within the downwind plume was considered to be the primary problem, as stated in the title of the project. A methodology from the literature enabled field data to be collected to measure salt deposition so that characteristic equations could be used to predict the quantity and location of the deposition. Several sampling episodes under a variety of operating conditions produced data that could be modeled to characterize the deposition. The average deposition of salts from the solar evaporator was less than 1 kg/hour and occurred within 200m of the source. A single sampling event when the most concentrated drain water was being evaporated produced the maximum of 3.5 kg/hr.
2. While it was not possible within the time and budget available to directly measure the small particles that remained in the air, it is possible to determine their significance with regard to the potential for regulation of a solar evaporator as a PM source. The particles produced by the solar evaporator were predominantly larger than those that would remain entrained as shown in the deposition patterns discussed above. The mass of deposited particles would be at least an order of magnitude and perhaps two greater than the entrained particles. The emissions of these particles which may be small enough to be classified as PM_{100} or $PM_{2.5}$ are insignificant compared to the levels that would result in regulation or even permitting of a facility. The threshold for permitting a facility is 12.5 tons of emissions/year. The threshold for regulation is 25 tons/year. The total salt emission rate (both deposited and entrained) from the solar evaporator would average about 1 kg/hr. This total, from continuous (24/7/365) operation of the solar evaporator would only be 9.6 tons/year. The particles small enough to be regulated are a very small fraction of that total so the PM emissions from the solar evaporator can be considered to be insignificant.

Results from this study have been discussed at the July and August meetings of the Agricultural Technical Committee of the San Joaquin Unified Air Pollution Control District. The conclusions regarding the emissions from the existing solar evaporator as being well below any threshold of regulation or permitting were accepted by that committee. Further discussion with air district staff regarding the effect of scaling up the evaporator to larger sizes will occur. An attempt will be made to get air district input regarding the facility size at which PM-10 emissions might reach levels requiring permitting.